

TM - 038

# VIDEO GAME

## OPERATORS HANDBOOK



ATARI INC. 14600 WINCHESTER BLVD. LOS GATOS, CA. (408) 374-2440 • TELEX • 357-488



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# CHAPTER I

## TEST EQUIPMENT

Essentially, video game troubleshooting consists only of checking for the presence and condition of various signals produced by the game. A signal acts like a messenger, carrying instructions from one unit or circuit to another. Since there are many different types of signals used, you will need several unusual types of test instruments with which you may not yet be familiar.

Depending on the desired depth of your intended troubleshooting capability, you will need a certain complement of instruments which visually demonstrate how a signal is behaving. The way in which the signal is displayed varies greatly according to the type of signal and the particular instrument used to test it. Instruments such as the logic probe use a system of flashing lights which you must interpret to reveal the state of the signal. Others use meters, digital read-outs, LEDs, cathode ray tubes and even the game's monitor itself.

Each instrument has its own set of advantages and disadvantages when used to examine any certain type of signal. Some, such as the video probe, are extremely limited as to the range of signals which can be examined while others, like the oscilloscope, have great flexibility. Some instruments are absolutely essential no matter what the size of your operation while others are desirable only because they make troubleshooting easier and quicker. And, of course, there is the inevitable and inescapable cost factor.

The range in cost and complexity of applicable test equipment can conceivably extend all the way from \$100,000 test computers right down to the inexpensive but invaluable \$1.00 video probe. Since you may be new to the video game repair field and somewhat confused by the diversity of test equipment, we will carefully analyze and compare the effectiveness and cost of each instrument in such a way that you can evaluate which instruments you really need and can realistically afford.

Wherever possible, we will recommend specific instruments which we have found to be most satisfactory, all things considered. Our criteria for making such recommendations is simple: adequate capability for the least cost.

## THE VIDEO PROBE

The video probe is an extremely simple, but invaluable piece of test equipment. The probe can be assembled in a few minutes from components which are probably already in your workshop. If you do not have quite all the parts, you can usually find them at any electronics parts house.

The probe is constructed from a length of 20 AWG (American Wire Gauge) rubber coated wire, a 4.7K, 1/4 Watt carbon resistor and two IC test clips (or one clip and one test prod). Our experimentation has revealed that the most convenient configuration is a single Mouser test clip (Mouser #131C 301 or 302) attached to one end of the wire and a test prod containing the resistor on the other.

To assemble the above type of probe, follow these directions:

1. Remove the cap from the test clip and strip 3/16" off both ends of the wire. Solder one end to the post in the test clip, thread the other through the hole in the cap and snap on the cap.
2. Unscrew the plastic body of the test prod from the point and trim both leads of the resistor to 3/16". Solder one lead of the resistor to the inside of the point. Thread the other end of the wire through the hole in the body, solder it to the other lead and screw the body back onto the point.

To use the video probe, simply attach it to the *negative side* of the video coupling capacitor and touch the prod to a convenient source of the suspected signal while watching the monitor for that signal's display. The location of the video coupling cap is found in the *video summing network* section of the logic schematic. A typical configuration is illustrated in Figure 1.

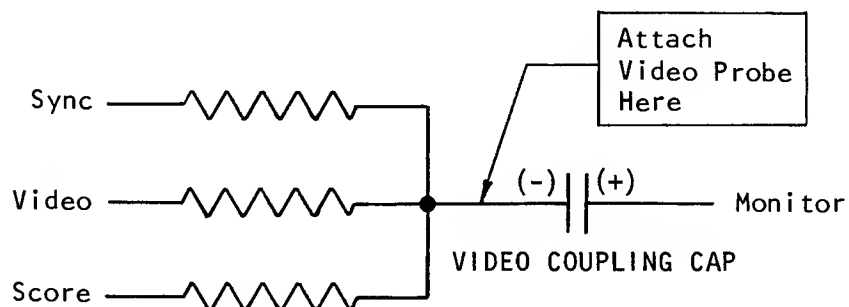


FIGURE 1  
LOCATION OF THE VIDEO COUPLING CAPACITOR

The video probe displays signals used in the development of other signals where the developmental signals are not otherwise visible on the monitor screen. The probe simply picks up the desired signal and couples it to the video line going to the monitor where it is directly displayed on the CRT (Cathode Ray Tube).

Figure 2 is a good example of a video probe picture. This figure shows a playfield shape in its earliest developmental stage.

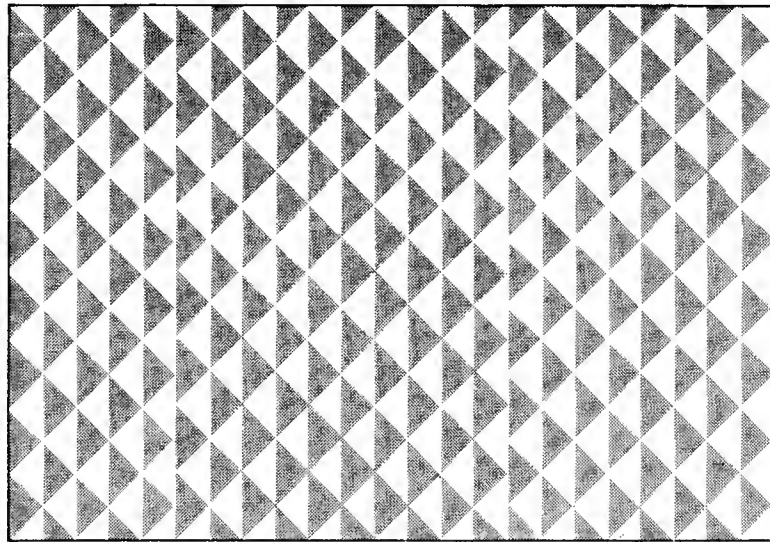


FIGURE 2  
A VIDEO PROBE PICTURE

The video probe is useful only for viewing *video* signals (e.g. those specifically designed to operate the monitor). It will not display extremely fast signals such as the CLOCK, nor will it display either very slow or analog signals. Its usefulness is therefore limited to viewing the outputs of video circuits such as sync, motion circuits, playfield generation and image display circuits.

## THE LOGIC PROBE

The logic probe is an instrument designed for fast verification of digital integrated circuit outputs. It is small, convenient to carry, easy to read and relatively inexpensive. It is a necessary and integral part of your test instrumentation. For general video game troubleshooting, the Kurz-Kasch model LP 520 is probably the best buy. It has all the features necessary to troubleshoot any Atari printed circuit board and its cost of \$77.00 is quite reasonable.

The logic probe derives its power from the system under test. A convenient place to attach the power leads of the probe is between the regulated +5 VDC side of the large (and usually HOT) wire-wound resistor and ground. This resistor is wired across the input and output of the LM 309 in the power supply area of the PCB. The schematic location is illustrated below, but the actual location of the resistor is indicated in Figure 12. Keep in mind, however, that the probe may be connected between any other source of +5 VDC and GND.

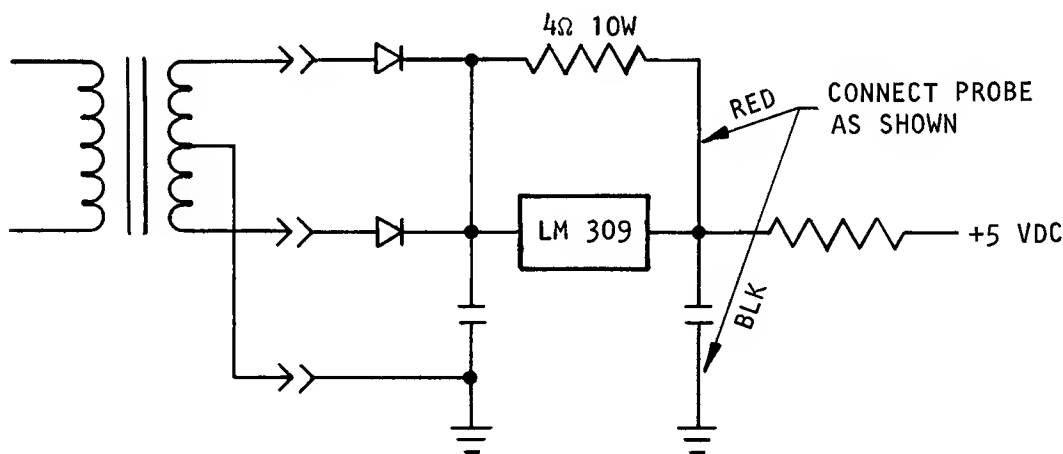
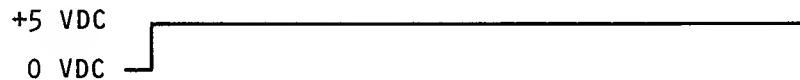


FIGURE 3  
VIDEO PROBE POWER CONNECTIONS

The condition or state of the digital signal is indicated by three lamps in the tip of the probe. The red lamp indicates a HI or logic level 1; white indicates the LO or 0 state and the blue indicates the signal is changing states. The specific voltages used for TTL components are +2.4 to +5 volts for a logic HI and 0 to +0.8 volts for LO. The area between +0.8 and +2.4 volts is known as the *grey* region and it is indicated by the fact that no lamps will light in the probe tip. A circuit which is shorted to ground will illuminate the white lamp and an open circuit will illuminate the red one.

In the illustrations below, the readout scheme is compared with how the signal would appear on an oscilloscope. You should notice that the logic probe can be used to get a rough approximation of the periodicity of the signal.



1. If the signal remains at a constant logic HI level, only the red lamp will illuminate.



2. Conversely, if the signal is L0, only the white lamp will be illuminated.



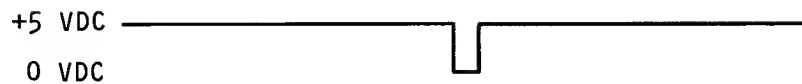
3. A symmetrical (square wave) clock source will illuminate the red and white lamps at half brilliance and the blue to full brilliance.



4. If the blue lamp flashes momentarily while the white lamp is at full brilliance, an otherwise L0 signal has pulsed HI once.



5. White and blue lamps constantly illuminated indicate the signal is pulsing HI repetitiously, but is mostly L0. The red lamp will illuminate if the duty cycle exceeds 10%, and the symmetry of the waveform can be roughly extrapolated from the relative brilliance of the red and white lamps.



6. If the blue lamp flashes momentarily while the red one remains illuminated, a L0 pulse has just occurred in an otherwise H1 signal.



7. Red and blue lamps constantly illuminated indicate the signal is mostly H1 with periodic L0 pulsing.



8. A blue lamp only indicates "noise" on the line.

Obviously, indications of signal periodicity are approximate at best, meaning the logic probe will never supplant the oscilloscope. However, often only very rough indications of periodicity are needed. For example, when checking a counter chain, all the outputs will be H1, L0 and PULSING which is not particularly revealing unless you consider that fact that you are simply trying to establish that the chip is outputting from all its output pins. The oscilloscope would reveal the precise waveform, however that degree of accuracy is not needed in most cases.

## THE TV SYNC PROBE

The LP 600 TV Probe is a new instrument developed by Kurz-Kasch specifically for troubleshooting video games. This probe is used when the video display is missing or distorted and it will tell you if the problem is in the monitor or the computer. There are many other techniques for doing this, but none so quick and easy.

For example, your malfunctioning game has a completely scrambled picture and you do not know if the monitor or the computer is causing the problem. To find out, simply attach the power leads of the TV probe to +5 VDC and ground and touch the probe tip to a convenient source of video output (either on the printed circuit board itself or at the connector to the TV monitor). If the probe lamps illuminate, the PCB is OK and the monitor is malfunctioning.

This probe functions by detecting the presence of correct sync signals which are produced by the computer. If the correct signals are present at the probe tip, the "brain" of the probe will measure them and light the lamps. If the signals are missing or the timing relationships between them incorrect, the lamps will not illuminate.

Since there are other means for verifying correct sync operation (e.g. with the video probe or the logic probe), the TV probe cannot be considered an absolutely essential instrument. However, if you feel at all uneasy about checking for sync by probing the PCB, the TV probe will prove quite useful. Aside from its low cost (about \$75.00), another feature of this device is that it is very easy to use in the field.

## THE LOGIC PULSER

The logic pulser is a necessary part of your instrumentation for it allows you to stimulate in-circuit ICs with a shaped, digital pulse. For example, a certain feature of the game is not working and you suspect the problem is that a circuit is not receiving the necessary signal. You use the pulser to immitate that signal and if the circuit begins to work, you have proven the signal is in fact missing and you can begin to track it down. This technique is very similar to jumping coils in electromechanical games such as pinball machines.

Like the logic probe, the pulser is connected to the system under test. When a node (another word for a convenient signal source) is pulsed, it is driven to the opposite logic level. If the line the pulser is connected to is L0, pressing the switch on the side of the pulser will introduce a HI pulse. Conversely, pulsing a HI line will pull that line L0 momentarily. The source and sink capabilities of the pulser override any IC output.

The cheapest and most versatile pulser is the Kurz-Kasch model HL 583. This unit is reasonably priced at about \$95.00 and has a feature many more expensive pulsers lack: a dual mode feature which allows the technician to introduce either a single pulse or a repetitious series of pulses.

In addition to the regular pulse button, there is a switch mounted to the unit. When set to the rep mode, it pulses the node at the rate of 5 Hz (five times per second). This extremely slow rate is used for it is slow enough to allow you to watch events initiated by the pulser. Counter outputs, for example, are more easily observed when the counter is pulsed or clocked at this rate.

## THE LOGIC COMPARATOR

The comparator is a device which, if it were less expensive, would be indispensable for it instantly checks if an IC is functioning correctly. However, evaluating its cost (well over \$600.00) against its effectiveness leads us to believe the money would be better invested in a good oscilloscope.

The comparator is essentially a simple device and works by comparing the suspected IC on the PCB directly with an identical reference IC in the instrument. Say you wish to check a chip marked 74193 but you are really not sure how this particular IC works. So, you insert a program card with a known-to-be-good 74193 into the comparator and then clip the comparator onto the suspected IC on the printed circuit board. If there are any logic state differences between the reference IC and the test IC, a lighted LED in the comparator will indicate which output is not functioning correctly. Once the bad chip is located, replacement is a simple matter.

Comparators are especially useful to those not fully familiar with all the integrated circuits used in video game computers. If you are not acquainted with the operation of a particular device, you have two choices: (1) get out your copy of the manufacturers data book containing a description of the suspected device and check its outputs with your other instruments, or (2) check it with a comparator without knowing how it works.

The comparator does have some serious drawbacks. For one thing, it will not help locate an open circuit, lines shorted to each other or failure in any analog circuitry. But more important, continued reliance on a comparator will get in the way of your becoming intimately knowledgeable with the operation of the ICs. Since a good understanding of the basic chips is the key to successful video game computer troubleshooting, we cannot stress this last point too much.

## THE LOGIC CLIP

Hewlett-Packard (and possibly others) markets a small device known as the logic clip (about \$75.00). This instrument has no extraneous wires or probes: it is simply clipped onto the IC in question. A number of LEDs in the top of the clip are arranged in the standard IC pin configuration and they illuminate whenever the pins they represent are HI.

Unfortunately, most video game signals are much too fast to observe in this fashion so the usefulness of this device is limited primarily to checking to see if the IC is powered and if certain other lines are tied HI or LO correctly. Extremely slow signals such as many found in the coin and credit circuits can also be observed. We have enjoyed watching especially slow counters with the clip because it graphically demonstrates the counting process. However, to be truthful, the clip has remained in the tool box ever since its initial fascination wore off.

Since the usefulness of this device is severely limited and the logic probe can be used to check the same things it will do, the logic clip must be classified in the optional category.

## THE OSCILLOSCOPE

If you are an electronics "lifer" buy the best and newest scope you can afford. If you are seriously interested in repairing video games, rent a good scope or buy an older one. If you are new to the business and intend only to "dabble" in video game repair, wait until you really need one.

Since TTL signals can be very fast, only the scopes with fast rise-time capabilities will do for video game work. Take that old scope you got with your home electronics course and throw it away. It won't even begin to work. To check most TTL circuitry, you will need a scope which is good to at least 25 MHz (keep in mind the computer clock runs at 14 MHz).

We prefer Tektronix scopes because they just seem to be better in very many ways. The newer scopes such as the 465, 453 and 454 are all solid state and are extremely accurate and easy to use. Of these three models, the 465 is probably the best. New 465s start at about \$1800.00 and go up depending on the options you get. Older 465s can be had anywhere from \$1400 to \$1800 depending on the amount of use. Older, tube-type scopes such as the Tek 530, 540 and 550 series start at about \$500 and go up to about \$1100. The tube type scopes are not quite as slick or as accurate and easy to use as their solid state relatives, but they do work adequately and they will heat your workshop nicely in the winter.

But whichever type you decide on, make sure to get the dual trace and dual time base capability. This feature enables you to examine both the input and output signals simultaneously to check precise timing relationships.

If you cannot afford to buy a scope outright, there are many other alternatives. You can take out a bank loan using the instrument as collateral or you can make financing arrangements through the dealer. Or, if you are not sure for how long you may need the scope, you can lease one under several different lease plans. Some plans will even allow you to credit the rental payments toward the purchase of the unit if you decide to buy at a later date.

## VOLT-OHMETERS

Everybody needs a VOM (Volt-Ohmmeter). They can be had so cheaply that nobody is priced out of the market. The instrument is extremely useful for checking line voltage, transformer secondaries, continuity, resistance, power supplies and, to some extent, analog circuitry. For example, the only way the analog hybrids in Gran Trak can be checked is with a VOM or with an oscilloscope.

There are many types of VOMs priced from \$15 to \$300. If you are seriously interested in electronics, get a good one (i.e. Simpson 260). You might even consider a DVM (Digital Volt Meter) which reads out the value directly on an LED display. DVMs are extremely accurate (three significant places) and are a good place to invest your money if you do need a high quality meter.

In any case, the VOM is an absolutely essential part of your test instrumentation. If you cannot afford anything else, get a \$15 one; you can even fix your car with it.

## THE TEST STATION

If you are going to repair any number of computer boards at all, you are going to need a test station. We keep hearing stories about guys with all kinds of equipment attached to boards still inside the game cabinet and we can hardly imagine any less comfortable way to work. So let's face it: you can test a PCB in a cabinet, but if you are going to do very many of them, you better get a test station.

In order to test any PCB, it must be connected to a suitable source of reduced line voltage, it must have a full set of player's controls attached to the proper PCB edge connector pins and it must have a monitor positioned in a convenient way. If you have the need for a test station, but not the money, make one yourself. All that is required is a full set of controls for each game (most controls are interchangeable) and a set of transformers. Since the PCB edge connector pins are arranged in various configurations from game to game, you will also need to make wire "interconnects" so that different PCBs can be plugged into the same station. The interconnect matches the PCB edge connector pins with those of the test station.

Test stations are currently available from your Atari Field Service Representative and will also be available shortly from Kurz-Kasch, Inc. The Atari test station contains a full set of controls which can be used to operate any Atari video game. Extra controls are provided to accomodate future games. The computer board is inserted in the side of the station and is positioned in a convenient way for connecting probes and other instruments. A program card is inserted in a receptacle in the top of the unit which takes the place of the old wire interconnect. The program card sets the fixture up for each particular game and each card has the name of the game clearly printed on it.

Any video monitor may be attached to the test station. The unit may be ordered complete with a monitor or you may provide your own.

Aside from the convenience offered by the test station, another reason for having one is that it can be used to actually troubleshoot the game. Since the station contains a known-to-be-good set of controls, harness and monitor, it can be used to perform a troubleshooting technique known as *substitution*. For example, the TV picture in the game is completely broken up and you want to determine if it is the game or the monitor which is causing the problem. Remove the computer board from the game and insert it in the station with the correct program card. If the game comes up on the station's CRT, you know that the malfunction lies in the game's monitor.

## MISCELLANEOUS ITEMS

There are a number of miscellaneous troubleshooting aids which you will need to pick up. First get a handful (at least four) of IC test clips (\$4.95 ea.). These small plastic clips are attached directly to the IC under test and they have two rows of metal posts projecting from the top where each post corresponds to one of the IC legs. The post offers a convenient place for attaching your test equipment as it is often difficult to attach a number of test devices to one IC without shorting two pins together.

Also, you will need a bunch of jumper wires. Normally, these are constructed from a short length (18") of rubber-coated 20 AWG wire with a Mouser IC clip on each end. Alligator clip will not work when dealing with ICs because they are so large that inevitably pins are shorted together. Jumpers are used to tie IC inputs either HI or LO or to input a signal from another circuit or device. If you wish, you may have black jumpers for tying inputs LO and red ones for pulling them HI.

## REPAIR TOOLS AND TECHNIQUES

Printed circuit boards are delicate creatures and require extreme care in handling and repairing. All tools used to repair PCBs must be small and of good quality. You do not use a pair of bolt cutters to remove an IC nor do you solder the new one in with a blowtorch.

## REMOVING COMPONENTS

Use extreme care in removing both ICs and discrete components. The soldering iron should be a 40 Watt unit with a small tip designed especially for IC work. If you can afford one, get a Weller Controlled Output Soldering Station (about \$35.00). This device assures an even and controllable tip temperature.

An IC is removed by the following process: first remove all the solder from *both* sides of the PCB. The solder is removed by first melting it with iron and then sucking it up with either a *solder-sucker* or with *solder-wick*. After all the solder is gone, remove the IC by gently prying it up. Clean the area thoroughly using an approved PCB cleaning solution to remove any traces of flux and dirt (alcohol will do in a pinch, if necessary).

Insert the new IC using an *IC insertion tool* making sure that the reference notch is oriented correctly and that the legs do not get bent as you insert it. Solder each leg on *both* sides of the PCB using as little solder as possible. Clean the area thoroughly to remove the flux.

When replacing discrete components, observe the same removal and insertion procedures. Make sure to trim the leads as close as possible and orient diodes and capacitors correctly.

## SOLDERING TECHNIQUE

Always use a 40 Watt iron with a small tip. Keep the tip *perfectly* clean so it shines at all times. Cleaning is done by wiping the hot tip over a damp sponge. Occasionally flux the tip and *re-tin* it with a small amount of solder to restore the finish. If the tip becomes encrusted with oxidized junk, replace it or use a file to expose a new surface.

Parts to be soldered must be absolutely clean and free of oxidation, dirt or grease. Wires should be first dipped in flux and tinned with a small amount of solder prior to final attachment. Always use rosin cored solder. Acid flux is not used in PCB work.

Heat both parts to be solder with the iron so that the solder melts on the parts, not on the iron. Never melt the solder with the iron and drip it on to the parts for the hot solder will land on a cold surface and a poor bond will form. This type of solder joint is known as a *cold solder joint* and is characterized by a bulbous shape and a dull finish. Typically, cold solder joints are very weak mechanically and have poor electrical characteristics. A good solder joint will be smooth, bright and the solder will have run into all the crevices of the parts smoothly and uniformly.

## REPAIRING PC TRACES

Sometimes, traces on the PCB are inadvertently cut in handling or are intentionally cut to permit certain troubleshooting techniques. If the cut away area is small, simply run a bit of solder over it. If it is too large to do this, lay a bare piece of 30 AWG wire over the trace and run a bit of solder over both the wire and the trace.

## RUNNING JUMPER WIRES

If you need to connect a permanent jumper wire from one IC to another, use only 30 AWG wire. Use as short a length as possible and try to run it under a number or other ICs to hold it down.

After repairing a PCB, be sure to firmly flex it a few times to make sure that the connections you made will withstand the stresses induced by normal handling.

## REPAIR TOOLS

Atari recommends the following list of PCB and harness repair tools:

ITEM MFG. PART NO. MFG. NAME DESCRIPTION PRICE

1.	95 AE	Erem	Diagonal cutters
2.	11D	Erem	Long nose pliers
3.	A90MS	Hunter	Tip-Dykes
4.	'A'	Erem	Tweezers
5.	MS-2	Hunter	Scribe
6.	No. 1	Xacto	Knife
7.	No. 16	Xacto	Blades
8.	X-A30-6	Hunter	Pliers
9.	99-PS-40	Xcelite	Hex kit
10.	PS-140	Xcelite	Screw drivers
11.	99-PS-51MM	Xcelite	Nut drivers
12.	W-TCP	Weller	Soldering iron
13.	WRAP	Kester	Solder, .031 flxd
14.	SS-011	Soldapullt	Solder sucker
15.	40-4-5	Solder-wick	#4 size
16.	#880		IC insertion tool
17.	47100	AMP	Wire strippers

In additon to the foregoing list, you should also have a bottle of pc cleaner and a small can of flux. Other desirable (but not absolutely essential) additions are a heat gun for use with shrink tubing and for locating intermittent thermal faults and a PCB vise for positioning the board at a convenient angle.



# CHAPTER II

## VIDEO GAME ARCHITECTURE

This section deals with the video game as a whole and its various sub-assemblies. Since successful troubleshooting depends on familiarization with the component parts from which the game is constructed, we have included this chapter to orient you to the general construction and operation of the game

A video game consists of a cabinet in which are mounted the players controls, the coin acceptor, a transformer, a printed circuit board, a TV monitor and a wiring harness which connects everything together.

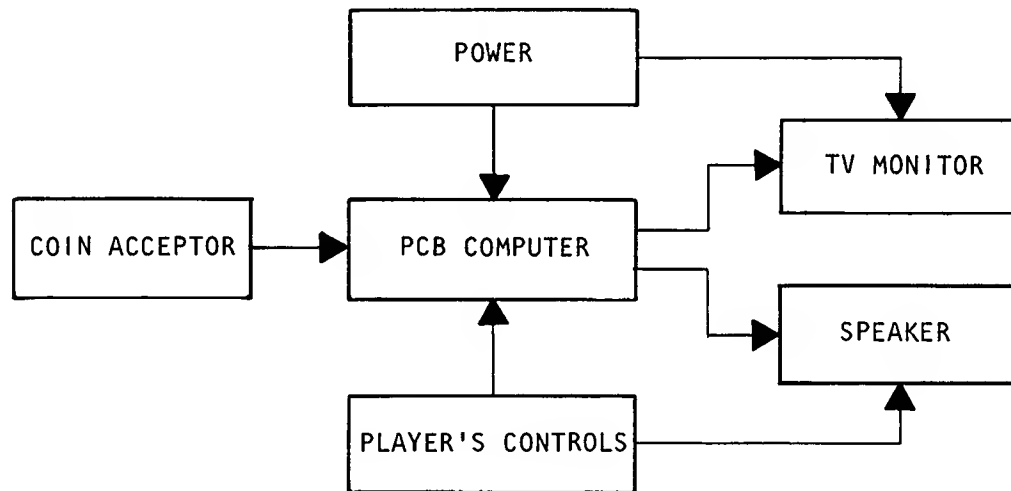


FIGURE 4  
GENERAL BLOCK DIAGRAM

The *player's controls* vary with the theme of each game and usually involve some sort of eye-hand coordination task pitting players against each other or against the computer itself. The *coin acceptor* is a mechanical device which detects and rejects undesired coins and completes a circuit only when a genuine coin is inserted. The *initial power supply* consists of a transformer which steps the line voltage down to a more convenient level for processing by the on-board power supply components. Some games may have a separate power supply PCB, but this has not been common practice.

The *printed circuit board computer* generates all the logic functions necessary to form the video displays on the CRT and move or change them as the game progresses. The PCB is a *dedicated* computer which means that it has been specifically designed for one purpose only and can therefore be used to operate only one particular game.

The PCB generates many types of signals, most of which are used internally. A number of these signals however are brought out through the PCB edge connector pins. Two of these signals, *sync* and *video*, are added together and become the input to the monitor. The sync signals synchronize the operation of the monitor with that of the PCB and the video signal *modulates* the monitor's electron beam to form images on the phosphorescent coating of the CRT (Cathode Ray Tube). Other signals generated by the PCB include *sound* signals which operate the speaker and *miscellaneous* signals which are used to operate special features such as lights, controls, etc.

The remaining PCB edge connector pins are either not used or used for inputs. Generally, the two right and left most pins are used for ground. Power enters several other pins from the transformer secondary. The player's controls are connected to as many other pins as are required by the particular game. The coin acceptor, start switch and antenna wire are likewise connected.

The confused mass of wire which connects everything together is called the *wiring harness*. For troubleshooting purposes, the interconnections between the coin acceptor, the player's controls, the transformer, the monitor, the speaker, the PCB and any other units are all illustrated in one drawing known as the *harness schematic*. The actual physical lay-out of the harness is shown in another drawing called the *enclosure wiring diagram*. The interconnections between the logic circuits on the PCB are found in a third drawing called the *logic schematic*.

## HARNESS COMPONENTS

In order to simplify the organization of this manual, we have lumped a few subjects together under the heading of "harness components". These include the coin acceptor, the player's controls, the transformer and the actual harness itself. The TV monitor and the PCB are discussed separately under those headings.

## PROBLEMATIC AREAS

Many malfunctions originate in the player's controls. This stems from two factors: (1) the total amount of use experienced by these mechanical devices and (2) the amount of physical abuse to which they are subjected. Specifically, malfunctioning pots and switches are the most common problems. Probably just as troublesome as the player's controls is the coin acceptor and we will fully explain acceptor maintenance and operation to end any confusion which might exist in this area. The next most problematic area is the harness itself, which -due to its rather delicate nature- offers its share of headaches in terms of broken or disconnected wires, poor solder joints, etc. The transformer is sometimes the cause of problems, so we will discuss it as well.

## PLAYER'S CONTROLS

For the most part, there are only two types of controls used to operate video games: potentiometers and switches.

The potentiometer or *pot* is a variable resistor and is found in all paddle games. The pot is used to control the position of the paddle on the playfield although in the future it may be used to control other types of images as well. Switches are just as common and are used in joysticks, driving game foot pedals and gearshifts, soccer game kick controls, in the coin acceptor and for a host of other applications.

## POTENTIOMETERS

Although there are very many different types of pots, only one is seen in video games. This is the single wiper, wire wound type with three external terminals (Figure 5). The resistance wire is wrapped around a flat strip which is bent into a circular shape and mounted to an insulated housing. A shaft, with a contact arm fastened to its inner end, extends through the housing and a knob is attached to the outer end. Shaft rotation causes the contact on the arm to slide over the windings of the resistance wire. Thus, the position of the contact determines the amount of resistance or *potential* between the center terminal and either end terminal. As the shaft is rotated, the resistance between the center terminal and one outer terminal *increases* while the resistance between the center and the other terminal *decreases*.

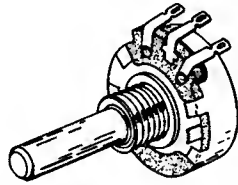


FIGURE 5  
A TYPICAL POTENTIOMETER

Most pots, even the "extended life" variety are simply not designed for the constant use given them in a popular game. They are particularly susceptible to small particles which get in between the contact and the resistance windings. This causes a momentary loss of contact or an excessively large resistance which produces the characteristic jerky paddle motion. The malfunctioning pot cannot be repaired; replacement is the only solution to this problem. Therefore, it would be wise to stock an extra pot for each paddle game you have.

When replacing potentiometers, keep in mind that there are several types used in video games. Normally, 5K pots are used, however one does come across other values in such games as World Cup Football. There are also normal and *extended life* varieties and it is advisable to replace bad pots only with the extended life ones (Allen Bradley Type J). The small difference in cost will inevitably save an expensive service call later (and also revenue lost to down time).

If, after you have replaced the pot, you notice the image seems to be moving in the wrong direction, do not get upset because all you have done is reconnected the wires in the reverse order.

## SWITCHES

The next most common type of control is the switch. There are many types of switches and often it is difficult to tell that a switch is actually the controlling device (e.g. when mounted to another actuating device such as a joystick). Push button or slide switches are often found mounted to the game's exterior control panel to control a play mode function of the game or to select the number of players. Micro switches are used in the coin acceptor and are also attached to joysticks, foot pedals, gearshifts, etc. Sometimes both a potentiometer and a switch will be mounted to one unit in games like World Cup where the pot controls paddle movement and the switch operates the "kick" feature.

Most switches will have three terminals: one is the *common*, the second is the *normally closed* side and the third is *normally open*. Generally, the terminal functions are indicated by the letter C, NC and NO above or near the associated terminals. To check such a switch, use a continuity tester or a VOM set to any of the R positions to make sure that the switch is making and breaking.

## JOYSTICK CONTROLS

Two types of joystick controls are currently in use: one uses dual, simultaneously actuated potentiometers and the other employs two or four micro switches.

The potentiometer version is considerably more complicated mechanically than the simple pot, hence is it liable to more breakage and maintenance. The adjustment procedure for this type of unit is also more complicated for it involves three simultaneous adjustments (see page 43). If you have a game with this type of control, it is advisable to stock at least one extra unit so that malfunctions can be quickly dealt with in the field. After you have removed the unit, you may chose to rebuild it yourself or you may return it to the game manufacturer for servicing.

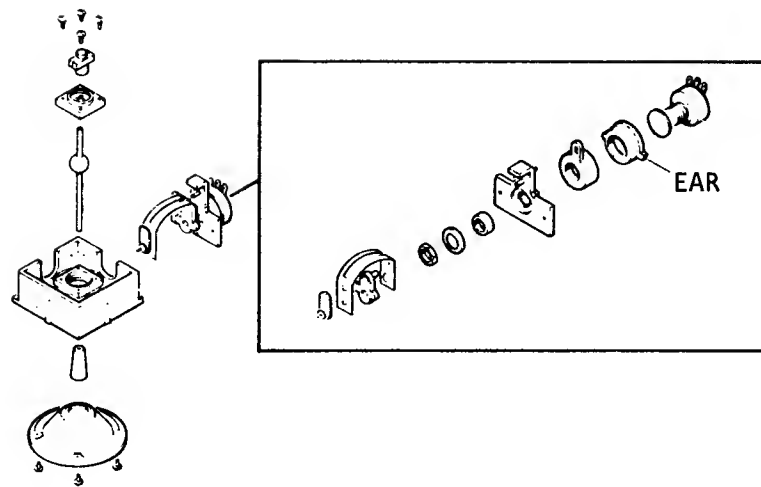


FIGURE 6  
THE KRAFT JOYSTICK

Most switch operated joysticks are quite sturdy and generally have a long life. The micro switches used in this unit are a common type and should be available from a wide variety of sources. The gearshift used in driving games is quite similar to the switch-actuated joystick, except that it uses a ball riding in a *detent* to produce the correct "feel". The major problem with this is cracked housings, so it would be wise to stock an extra as ordering one takes some time. In a pinch, a cracked housing may be temporarily repaired by securing the housing with an aircraft type hose clamp until the replacement arrives.

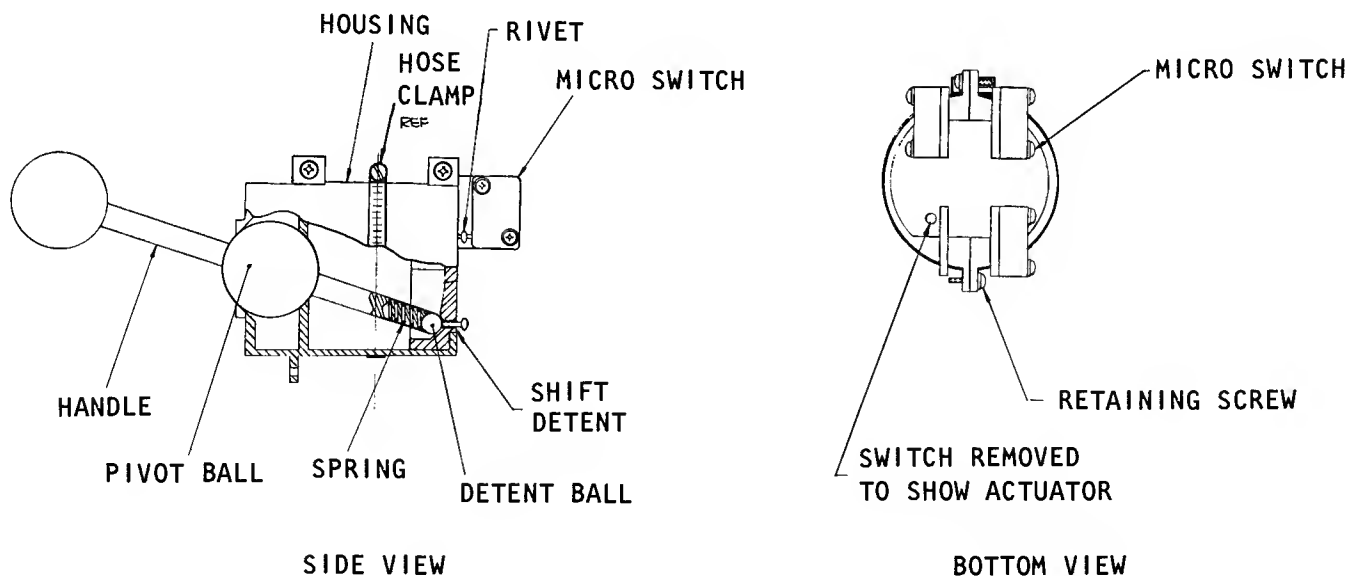


FIGURE 7  
GEARSHIFT ASSEMBLY

## COIN ACCEPTORS

Malfunctioning coin acceptors often account for more headaches than any other single problem related to video games. This stems mainly from misinformation regarding proper adjustment and maintenance procedures for acceptors. Lack of readily available service literature has led to inadequate maintenance resulting in repeated service calls for particular machines, even by operators who otherwise make every effort at correct and timely machine maintenance.

Coin acceptors are simple mechanical gadgets, easy to keep running once their operation and weaknesses are understood. Believe it or not, a properly "tuned" acceptor should never fail to work correctly unless jammed by a coin or slug.

A great variety of coin acceptors are produced by manufacturers all over the world and a number of different ones are found in video games. However, all of these acceptors share an almost identical construction, a factor which makes our task considerably easier. A typical acceptor widely used in the industry is the Coinco Q530 quarter acceptor<sup>1</sup>. The following acceptor information is based largely on factory service procedures recommended by Coinco, but it should also apply to any make of acceptor you find in your machine.

Most coin acceptor problems stem from improper adjustment of the magnet gate assembly (Figure 9). A gate which is adjusted with too large a gap may pass both genuine and counterfeit coins. Adjustment in the other extreme results in rejection of some or all the coins. To compound this problem, the screw which adjusts the magnet gate has a tendency to work loose over a period of time resulting in a gradual narrowing of the gate. At first, only the thickest (i.e. the newest) coins are rejected. As time passes, more and more coins are rejected until finally a complaint is made and the machine serviced. This particular problem is dealt with by first following the adjustment procedure outlined in the following pages and then by permanently fixing the troublesome screw in place with a drop of glue. If the mechanism is properly adjusted at this time, it should be years before the acceptor has worn to the extent where it will require another adjustment.

<sup>1</sup>More information regarding this and other Coinco acceptors is available from your area Coinco representative, or by writing Coinco, Inc., St. Louis, Missouri 63110

## Q530 COIN ACCEPTOR OPERATION

The detection and rejection of undesired or counterfeit coins are determined by size (both thickness and diameter), weight and metallic composition.

The *transfer cradle* (#9 in Fig. 9) is used to test both the size and the weight of the coin. The quarter must first pivot an *undersize lever* (14) to unlock the transfer cradle. Undersize "quarters" will fail to unlock the transfer cradle and can be returned by actuating the *wiper operating lever*. Oversize diameter coins will fail to pass between the transfer cradle and the wiper and can be returned by operating the wiper lever. Coins that are oversize in thickness will fail to pass between the *magnet gate* (15) and the *main channel* (7) and will have to be dislodged by actuating the wiper operating lever. Underweight coins will fail to overcome the transfer cradle *counterweight* and can be returned by operating the wiper lever.

A *magnet* is used to test the metallic composition of the coin. Highly magnetic coins, such as steel or iron, will be retained by the magnet and can be returned by actuating the wiper operating lever. Coins having comparatively high magnetic properties will be slowed down by the magnet and will drop off the end of the rail short of the *accept* entrance (Figure 8) and will be returned. Coins having little or no magnetic properties, such as brass or zinc, will pass through the magnetic field so fast they will overshoot the *accept* entrance and will be returned.

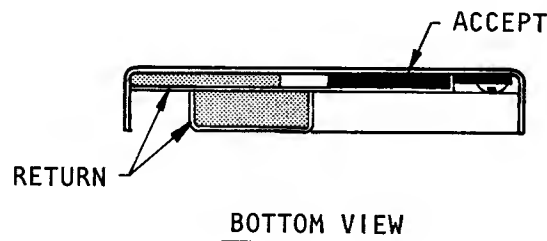


FIGURE 8  
COIN ACCEPTOR

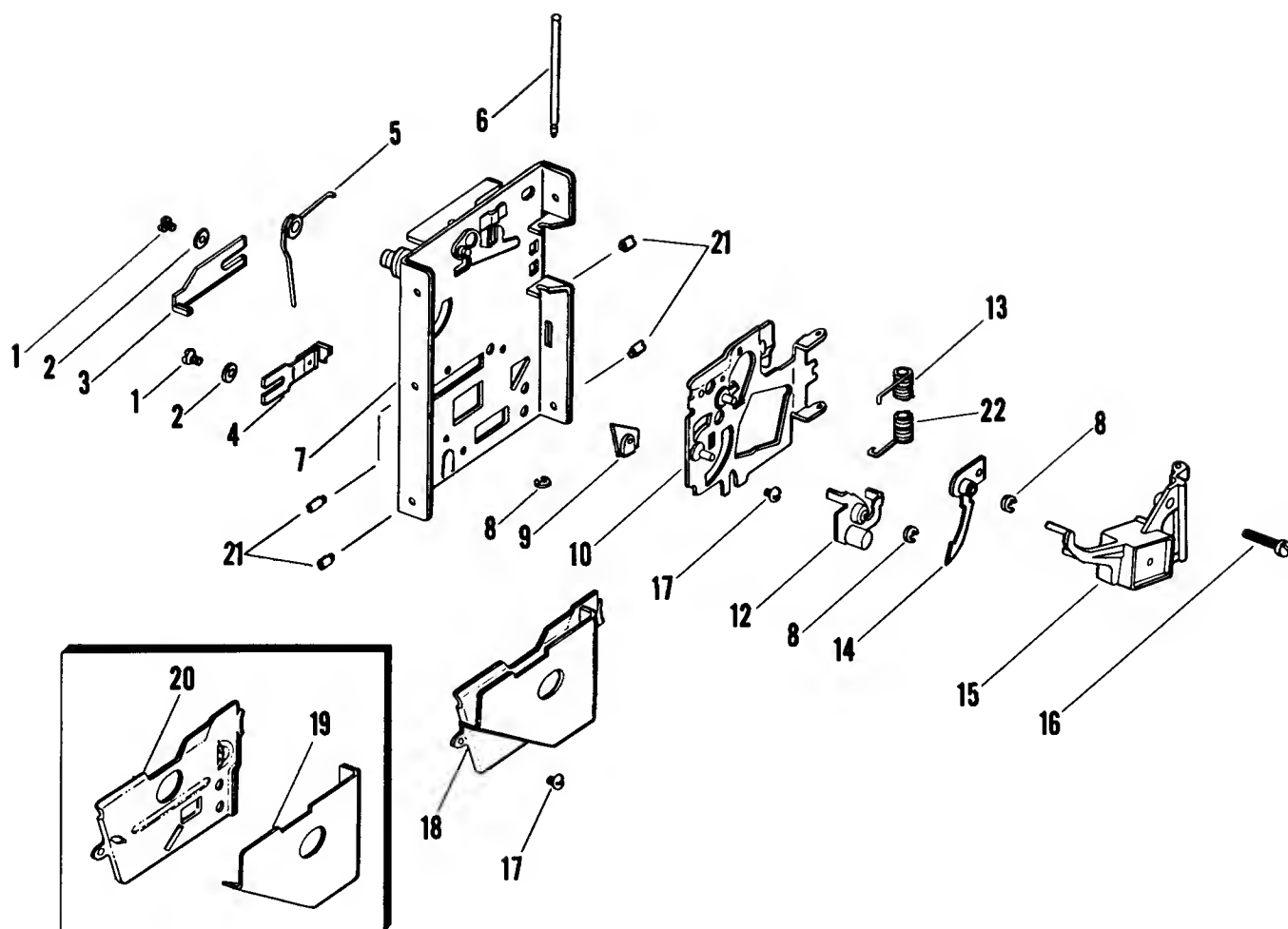


FIGURE 9 COIN ACCEPTOR EXPLODED VIEW

- |    |                    |    |                          |
|----|--------------------|----|--------------------------|
| 1  | KICKER SCREW       | 13 | UPPER GATE PIVOT SPRING  |
| 2  | WASHER             | 14 | UNDERSIZE LEVER ASSEMBLY |
| 3  | KICKER             | 15 | MAGNET GATE ASSEMBLY     |
| 4  | SEPARATOR          | 16 | MAGNET GATE ADJUSTER     |
| 5  | GATE LEVER SPRING  | 17 | RETAINING SCREW          |
| 6  | GATE PIVOT PIN     | 18 | COVERPLATE ASSEMBLY      |
| 7  | MAINPLATE ASSEMBLY | 19 | RETURN COVERPLATE        |
| 8  | "C" WASHER         | 20 | COVERPLATE               |
| 9  | RAIL               | 21 | MOUNTING STUDS           |
| 10 | GATE ASSEMBLY      | 22 | LOWER GATE PIVOT SPRING  |
| 12 | CRADLE ASSEMBLY    |    |                          |

## ADJUSTMENT

All coin acceptors leave the factory pre-adjusted for maximum performance. If, however, more critical adjustments are desired, or if the unit has been completely disassembled for service, the following procedure is suggested.

If the coin acceptor has been removed from the machine, place it in a vertical position on a level surface (test position). If the acceptor is still in the coin door, be sure that the entire assembly is held vertical.

### A. KICKER AND SEPARATOR

1. Set the acceptor with the back of the unit facing you in the test position.
2. Loosen the screws holding the kicker (1) and the separator (1) and move the kicker (3) and the separator (4) as far to the right as they will go.  
Lightly tighten the screws.
3. Insert several test coins (both old and new) and note that some are returned by striking the separator.
4. Loosen the separator screw and move the separator a slight amount to the left. Lightly retighten the screw.
5. Insert the test coins again and, if some are still returned, repeat Step 4 until all the coins are accepted.
6. Loosen the kicker screw and move the kicker as far to the left as it will go. Lightly retighten the screw.
7. Insert the test coins and note that some are returned.
8. Loosen the kicker screw and move the kicker a slight amount to the right. Lightly retighten the screw.
9. Insert the test coins agains and, if some are still returned, repeat Step 8 until all the coins are accepted.
10. Be sure that both screws are tight after the adjustments have been made.

## B. THE MAGNET GATE

1. Set the acceptor with the front of the unit facing you in the test position.
2. Turn the magnet gate adjusting screw (16) out (counterclockwise) until none of the coins will fit through.
3. With a coin resting in the acceptor entrance, turn the adjuster in (clockwise) until the coin barely passes through the magnet gate.
4. Test this adjustment using several other coins (both old and new) and, if any fail to pass through the magnet gate, repeat Step 3 until all the coins are accepted.
5. Fix the magnet gate adjusting screw in this position with a drop of glue.

## MAINTENANCE

Depending on the environment in which the acceptor is used, periodic maintenance should be performed.

The mainplate (7) may be cleaned with any household cleaner. Thorough rinsing and drying are necessary to remove deposits and/or film. Remove all metal particles from the magnet by guiding the point of a screwdriver along the edges of the magnet. Remove the transfer cradle and undersize lever and clean the bushings and pivot pins. Apply powdered graphite or pencil lead to the pivot pins and bushings and reassemble. Spray the entire unit lightly with WD-40.

## THE TRANSFORMER

The function of the transformer is to reduce the 117 VAC line current down to more usable voltages. The simplest games require only a single 16.5 VAC output which is used by the PCB power supply components to generate the +5 VDC required for the integrated circuits. Other, more complicated, games may need additional voltages such as +18 VDC or -12 VDC to operate sound circuitry, ROMS, etc. In this case, you will find a 25 VAC circuit in addition to the 16.5 VAC one. Games which have incandescent lamps used for general illumination purposes will normally have a 6 volt secondary as well. In this case, the lamps are powered directly with 6 VAC.

If you suspect you might have a bad transformer, check both the primary and secondary voltages with a voltmeter. The line voltage connected to the primary should never drop below 105 VAC, or game credit problems will result. If there is no voltage at the primary terminals, check the fuses, line cord, etc. Check the secondary outputs (there may be as many as three) using the legend on top of the transformer. This legend will correlate the various taps with the voltages produced from them. If you do not find a legend on the transformer, consult the logic schematic for the information.

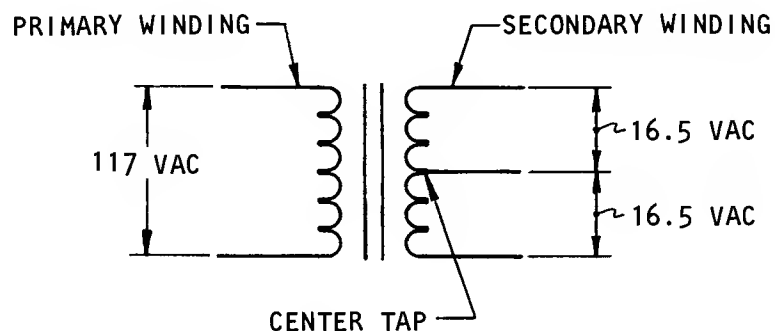


FIGURE 10  
TRANSFORMER SCHEMATIC

## THE PRINTED CIRCUIT BOARD

Most printed circuit boards have many features in common and an effort has been made to locate components in a logical fashion. The ICs are arranged in a grid pattern bordered on the top by letters and on the side by numbers so that individual ICs may be identified by their actual grid locations. For example, chip H7 is located at the intersection of the H column and the seventh row. Pins are identified by a third number. In this case, H7-1 refers to the first pin to the left (CCW) of the reference notch (see Figure 11).

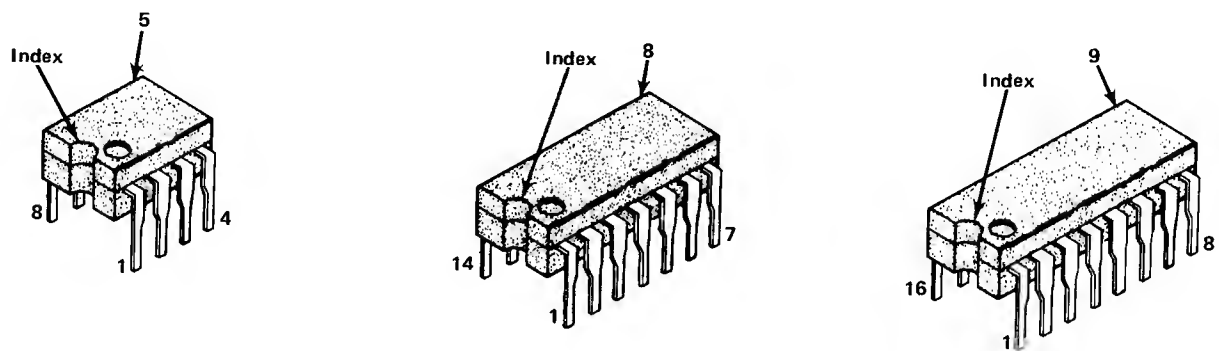


FIGURE 11  
IC PIN CONFIGURATIONS

The reference notches (or indentations in some cases) are all oriented in the same direction and care should be observed in this regard when installing new chips. Each chip is identified in the *stuffing chart* (Figure 12) by a 7400 or 9300 series part number. This is the number you use when looking up that chip in the manufacturer's data book. Actual chips have two or more numbers. One is the manufacturer's part number (sometimes there will be two different manufacturer numbers). Another is a date code. A third number may indicate the batch number. The date code is sometimes a cause of confusion because chips manufactured in 1974 have date codes which resemble 7400 series part numbers. If in doubt, crosscheck using the information in the logic schematic.

Generally speaking, chips used in the same circuit are located near each other. This is a natural result of the necessity to keep traces as short as possible to avoid picking up noise and other undesired signals.

All logic circuits (and every other electrical load for that matter) are connected to a common return called *neutral* or *ground*. A main ground buss runs around the outside edge of the PCB. Smaller ground busses pass down the rows of ICs and each IC is connected to ground by at least one pin. Generally, pin 7 of a 14 pin package is grounded. Other pins may be connected to ground to provide a logic L0 at that input. The main ground buss runs underneath the LM 309 voltage regulator to ground it, to any other discrete components needing to be grounded and finally out to the pins on the extreme left and right sides of the PCB edge connector.

Power is distributed to the components in a similar fashion. The power buss carries +5 VDC and runs directly underneath the ground buss on the underneath of the PCB. Plated-through holes power the smaller busses which in turn power the individual rows of ICs. Pin 14 of a 14 pin DIP (Dual In-line Package) is usually the power pin. The +5 VDC line is not necessarily associated with any particular edge connector pin nor are the transformer secondary input pins. This is why plugging the wrong board in a harness (or plugging the right board in upside down) can have catastrophic effects.

The flat capacitors which are connected between the power and ground lines (C10-C16 in Figure 12) are known as *bypass* capacitors. Their function is to suppress noise on the 5 VDC line. A spike or transient appearing on the line will charge the capacitor and therefore be eliminated.

The majority of the discrete components are located on the end of the PCB nearest the edge connector. These resistors, capacitors and such are called *discretes* for they are individually *distinct* entities as compared with ICs which are a number of components *integrated* together as a whole.

The most prominent features of this part of the PCB are the filter capacitor and the LM 309. Both are used in the power supply. The filter cap (usually 8000 Mf) produces a *pulsating DC* voltage in conjunction with other components and the LM 309 is an integrated voltage regulator which assures an even, steady +5 VDC line. The aluminum gizmo around the LM 309 is a *heat sink* which cools

the device and allows it to output its maximum current. A large *wire wound* resistor ( $4\Omega$ ) is connected across the input and output of the LM 309 to increase the current capability of the power supply. It is quite normal for this resistor to become extremely hot after the game has been energized for a few hours. Some recent games which have especially large computers use an LM 323 which is good to about 3 Amps.

The component which looks like a flattened can is the crystal (XTAL) and it outputs a 14.318 MHz frequency. This frequency is shaped and amplified by other components in the *oscillator circuit* to produce CLOCK, the master timing signal for the computer. Occasionally, a stopped crystal may be restarted by firmly tapping it. If it will not restart, replace it after checking the rest of the circuit components.

The round blue devices which have a small screwdriver slot are *trim pots*. These function like any other potentiometer and are used to adjust paddle travel, play time and other features.

At least one slide switch is found on every PCB. Slide switches are used to adjust the credit circuit (one or two plays per coin), the point at which the game ends (11 or 15 points) or whether a replay is awarded at a certain score. The insides of the slide switch are open to the outside world, so contamination by foreign material (such as flux during the flow soldering process) is a common problem. If the feature controlled by a slide switch does not work properly, first try cleaning the switch by spraying a small amount of contact cleaner into it and working the switch back and forth several times. If the feature is still inoperative, check the circuit by jumping the switch. If the feature suddenly begins working, replace the switch.

Many of the resistors are *pull-ups* which means they are used to tie an input to an IC at a logic HI level.

Also, don't worry if you see an empty IC socket. Nobody left an IC out, rather the socket is used to accommodate another chip should a modification or additional feature become necessary. For example, the game Pin Pong has several empty sockets. Two of these are used to accommodate chips which enable the game to be operated in foreign countries using a 50 Hz line frequency.



## FUNCTIONS OF COMMON CIRCUITS

The following description of video game computer functions is extremely simplified and is included here only to orient you to the names and functions of common circuits. Greater understanding of individual circuit can be achieved by reading the in-depth circuit descriptions provided for certain Atari games. A good example of PCB circuit analysis is the Gran Trak 10 Computer Service Manual which has been reprinted at the end of this manual.

The Power Supply receives a reduced voltage from the transformer and outputs +5 VDC and possibly other voltages depending on the types of devices used. The Oscillator produces CLOCK, the master timing signal for the entire system. The clock frequency is divided  $2^9$  times by the Horizontal Sync circuit to produce *clock submultiples* which are combined in various ways to generate H RESET, H BLANKING and H SYNC. The Vertical Sync circuit divides H RESET  $2^9$  times to produce vertical submultiple which are used in the formation of V RESET, V BLANKING and V SYNC. H SYNC and V SYNC are combined to form COMP SYNC, the signal which synchronizes the monitor with the computer.

The Horizontal Motion and Vertical Motion circuits are closely related to their sync circuit counterparts and they control the *direction* and *velocity* of the moving images. The Object Display circuit creates the actual subject image which is moved by the motion circuits. The Coin and Credit circuitry records the deposit of a coin, provides game credit, starts and stops the game as well as providing important anti-cheat functions. Some sort of a Game Length circuit, whether it be a timer or a score counting arrangement, determines when the player has had enough and outputs a signal which disables game credit via the credit circuit. Score Storage counts the score producing events, stores the information and directs the score display circuit to display the correct score on the CRT. The Playfield Display section is sometimes very small or occasionally quite large. It generates the stationary background images. The Sound circuitry is operated by score events or other events depending on the game and the sound signals are amplified before entering the speaker. All the video signals are added together in the Video Summing network before entering the TV monitor.

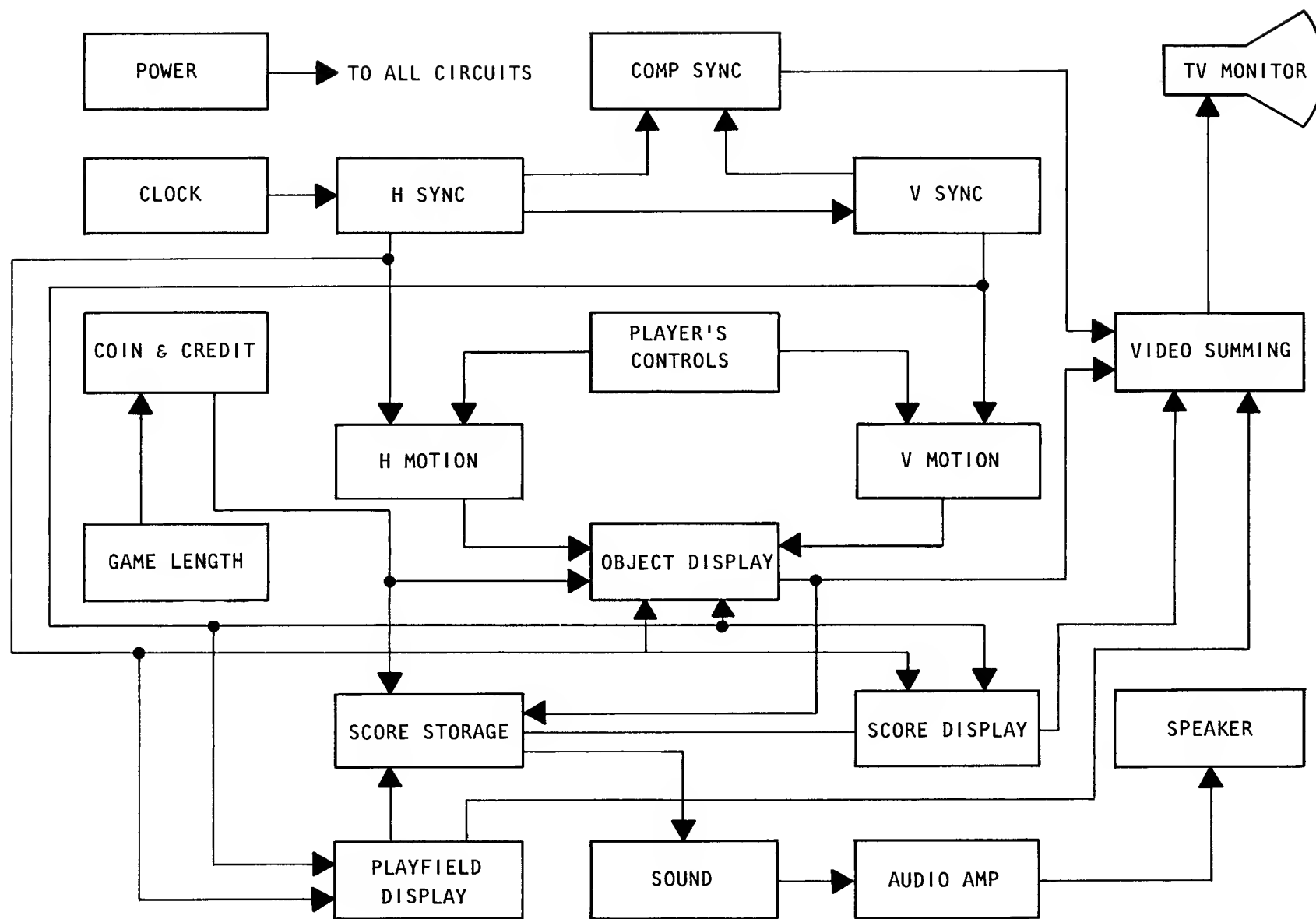


FIGURE 13  
GENERAL PCB BLOCK DIAGRAM

## THE TV MONITOR

Virtually all the timing relationships between computer events are engineered to be compatible with the operation of the TV monitor. This being true, some understanding of the relationships between the various sync signals and the movements of the electron beam is desirable to build a basis for later comprehension of computer circuitry.

Video game monitors (and all TV receivers) use the *raster scan* display method. The electron beam in this case scans the CRT in a pattern or raster which is endlessly repeated. Images are created by *modulating* or *intensifying* the beam when it has reached the correct point. Depending on the degree of modulation, points of differing intensity are illuminated. In other words, the greater the amplitude of the incoming video signal, the more powerful the electron beam becomes and the affected areas of phosphor glow more intensely. The type of phosphor used in the monitor is selected for its color and its degree of *persistence*.

Persistence describes the phenomenon which causes the image to linger for a period of time even after the electron beam has moved on to a new point. If a very bright image is directed on the same place on the CRT for a protracted length of time, the phosphor in that area may become permanently *burned*. Replace the CRT only if it becomes objectionable.

There are several types of rasters, however only two are used in video games. The more important of the two is the *non-interlaced* scan, but a few games such as Gran Trak have used the *interlaced* raster technique (pages 2-4 and 2-5 of the Gran Trak manual).

Figure 14 is a simplified illustration of the non-interlaced raster. In this case, the electron beam begins the new frame in the upper left corner of the CRT and sweeps out one horizontal line ending at the right side. The beam is then repositioned back to the left side by a process known as *horizontal retrace*. During retrace, the electron beam is *blanked out* so no undesired illumination can occur. Retrace blanking is an internal function of the monitor and is not related in any way to blanking signals produced by the computer except that both occur more or less simultaneously. The computer signals H BLANKING and V BLANKING are used in the development of the sync signals and to load new information into the motion circuit counters.

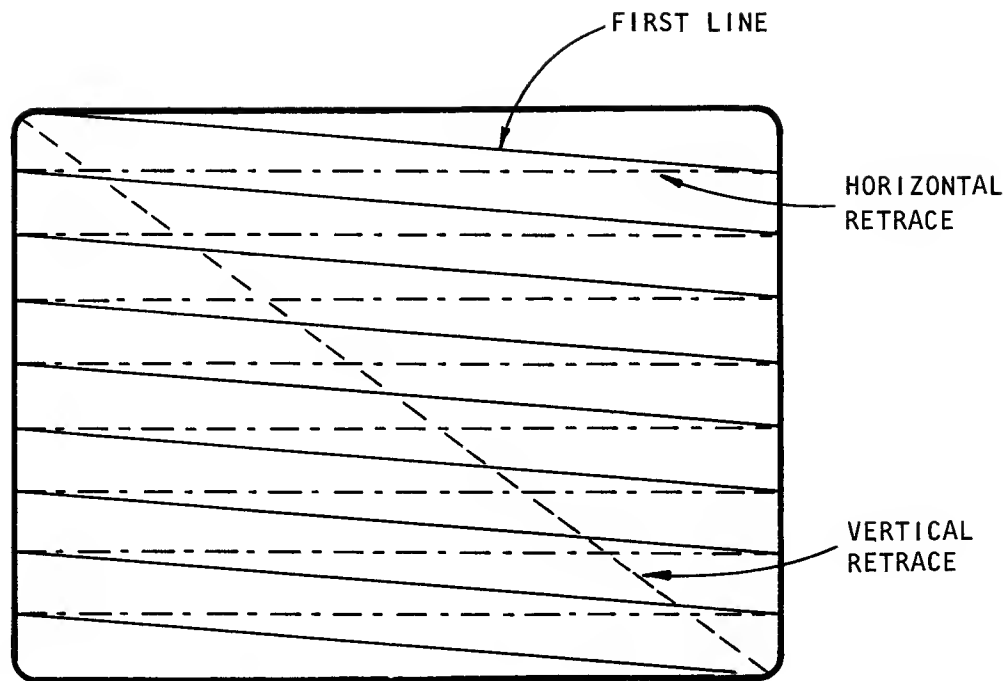


FIGURE 14  
NON-INTERLACED RASTER SCAN

After the electron beam has been reset to the left side again, it sweeps the second horizontal line. Since the beam is deflected vertically as well as horizontally, the second line appears beneath the first. The beam continues to scan in this fashion until the end of the last line which is located in the lower right corner of the CRT.

At this point, both a horizontal and a vertical sync pulse occur and the electron beam is reset back to the left and top of the CRT simultaneously to the point of its beginning. The reset process is known as *vertical retrace* and the video information is blanked out during this time.

Each time the electron beam has scanned the entire CRT, it is said to have completed one full *field* which contains 262 horizontal lines. In the non-interlaced raster scheme, successive fields are laid approximately on top of one another. Two complete fields constitute one *frame* and the frame rate is 30/sec.

When the monitor is not receiving incoming sync signals, it operates in the *free running* mode. In this case, it simply generates a raster not timed with the operation of any other device. When connected to a video game computer, it locks onto the sync signals and is therefore *synchronized* with the operation of the computer. The generation of PCB sync signals is precisely timed so the electron beam begins each line as an H SYNC pulse occurs. The frame begins with a vertical sync pulse.

## DEFINING CRT LOCATIONS

The monitor generates a raster containing 262 horizontal lines where each line contains 454 separate points which may be illuminated to form an image. In order to illuminate a desired point, the point must be *addressed* so that the electron beam is intensified exactly as it reaches the desired horizontal and vertical position. This is done by providing a set of coordinates for each separately addressable point.

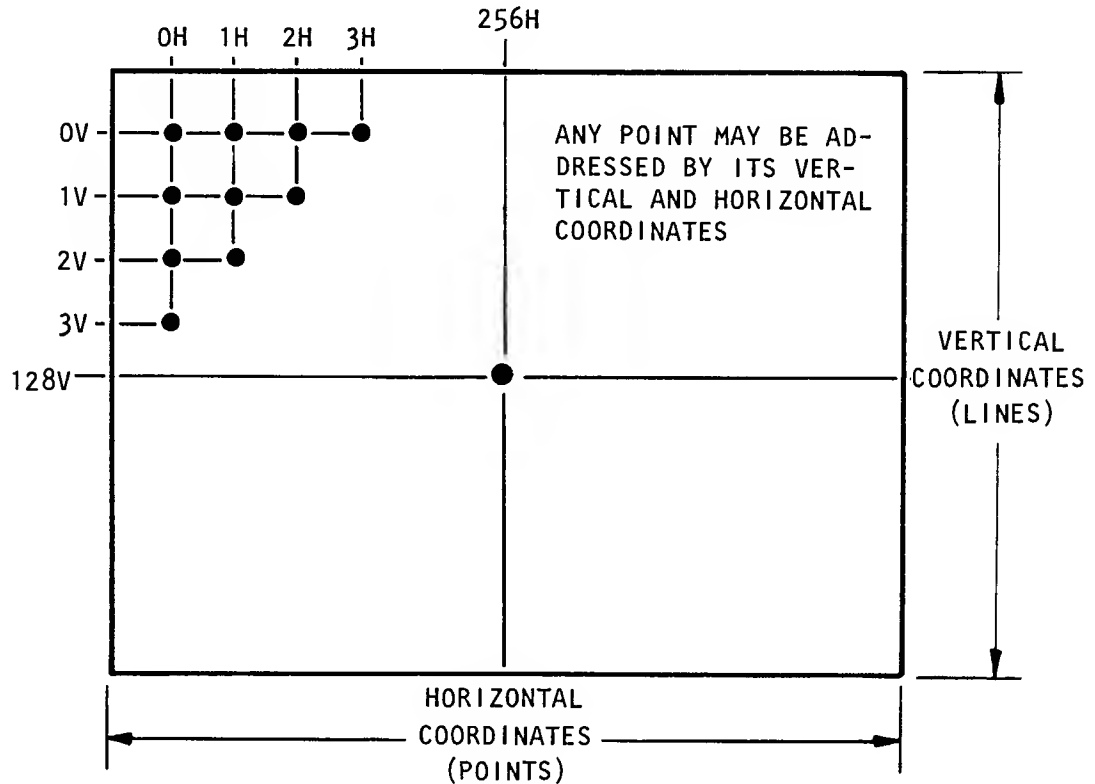


FIGURE 15  
CRT LOCATION NOMENCLATURE

The nomenclature associated with this coordinate system is illustrated in Figure 15. Notice that each *horizontal* line of the raster has a *vertical* position down the screen. The first line is denoted 1V (meaning *1st vertical*). Successive lines ascend numerically until the last line (262V). Therefore, each horizontal line has a separate vertical number or address.

Each point along every horizontal line also has a location or number. The first point occurs in the upper left corner of the CRT and is denoted 1H (or *first horizontal* point). The second point is 2H, the third 3H and so on until the end of the line which occurs at 454H.

The combination of the vertical and the horizontal address produces a set of coordinates for every point in the raster. For example, to illuminate a point approximately in the middle of the CRT, we would need to intensify the electron beam as it reaches the intersection of 128V and 256H.

One can visualize the CRT as a rectangle bounded on the top and bottom by 0V and 262V and on the sides by 0H and 454H. Since points and lines are spaced approximately equidistant, a shape 4H by 4V will be approximately square.

The entire computer-generated picture is not visible. The viewable area is illustrated in Figure 16 and although computer events do occur while the electron beam is not within the viewable area, they will not be displayed. Since the viewable area is slightly offset, it must be centered symmetrically within the actual borders of the CRT. Various adjustments (page 45) are used to position the picture so that 256H and 128V describe the approximate center lines horizontally and vertically. The horizontal and vertical size and especially the yoke adjustments affect the position of the picture.

The oscillator frequency (CLOCK) has been chosen to exactly match the number of points per line. In other words, each line contains 454 clock pulses.

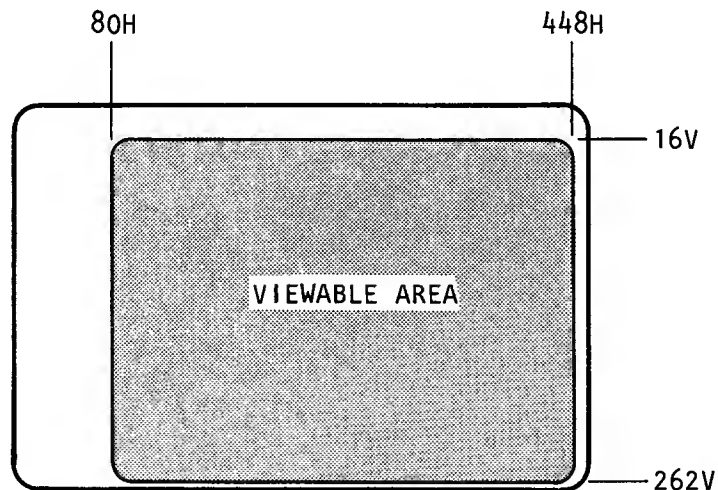


FIGURE 16  
VIEWABLE AREA

## THE HARNESS

The actual harness consists of the bundle of wires which connects all the sub-assemblies together. A typical harness schematic diagram is illustrated in Figure 17. The harness schematic shows only the electrical information. The wiring diagram (Figure 18) shows the physical layout of the harness, the wire colors and the various connections to components.

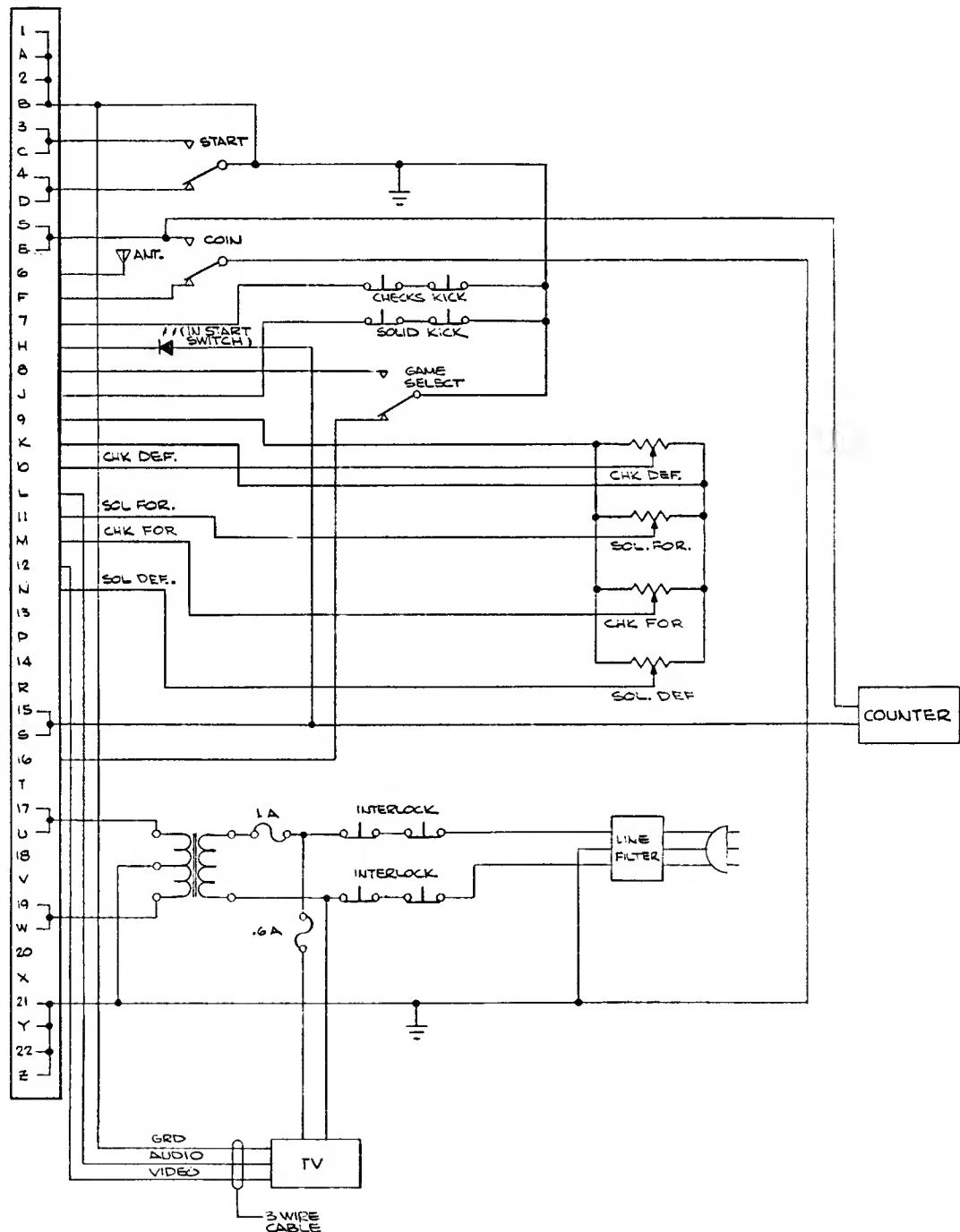


FIGURE 17  
TYPICAL HARNESS SCHEMATIC

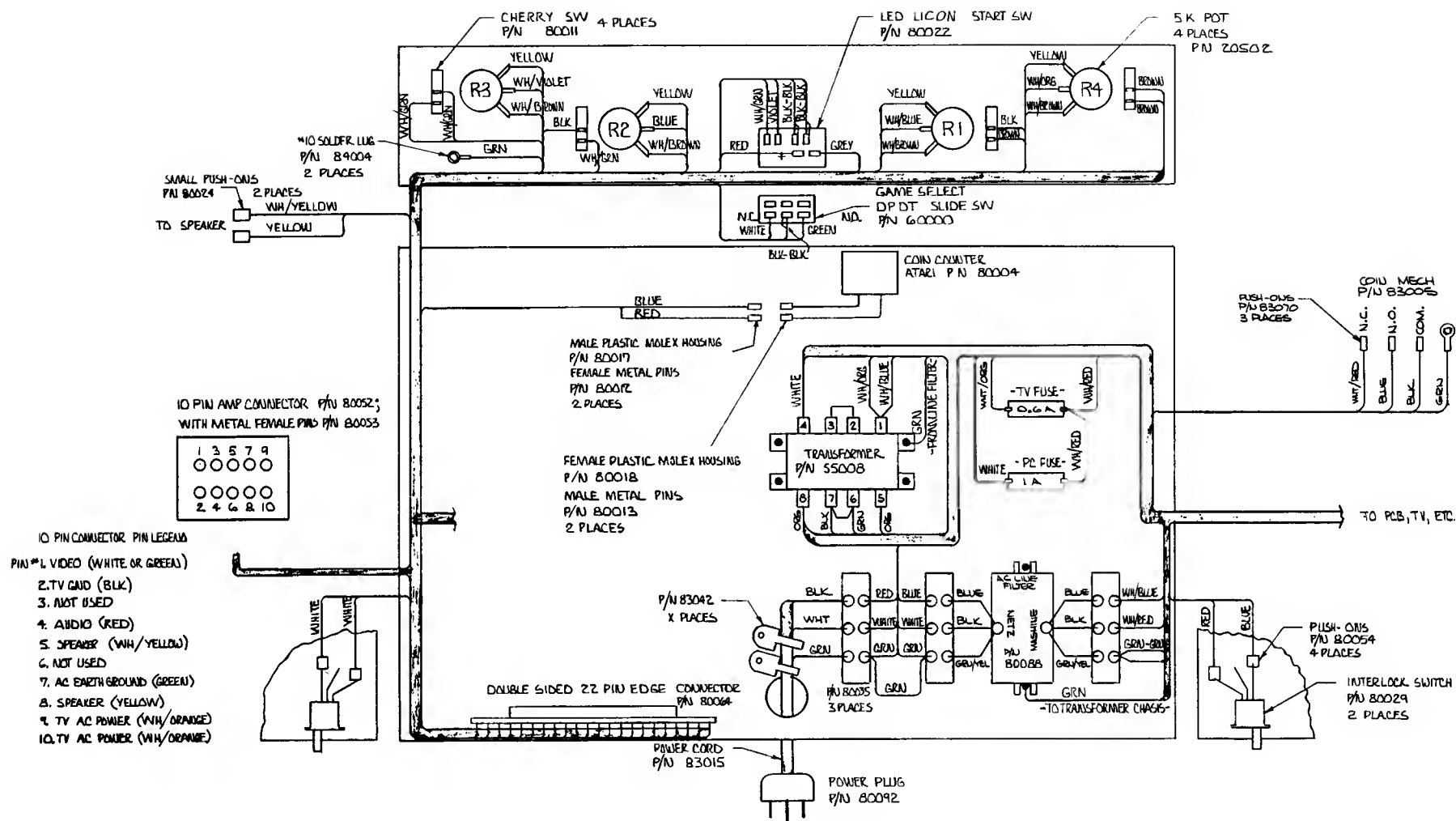


FIGURE 18  
TYPICAL WIRING DIAGRAM

The first thing to notice is that the line plug has three prongs on it: one hot, one neutral and one grounded. Never cut off the ground prong because your wall receptacle does not have a place for it. The ground prong is there for a reason: to protect you and others from a possible 20,000 volt lethal shock which can be produced by a malfunctioning TV monitor. If your building is not equipped with grounded receptacles, get an adaptor. The adaptor will adapt a three prong plug to an ungrounded (two prong) receptacle. The adaptor also has a short length of wire projecting from the side. Take this wire and attach it to a good earth ground. Normally this is done by clamping it to a water pipe with a special clamp available at hardware stores. Then, just to be on the safe side, measure the resistance between the neutral wire and the grounded wire using the VOM. There should be no noticeable ground potential.

The *line filter* is used to prevent transients and other voltage fluctuations from disturbing the operation of the power supply. Essentially, the filter performs the same function as the bypass capacitors. Not all games have line filters.

From the filter, the line voltage passes through two *interlock* switches and then to the transformer. A switch is mounted on both doors in such a way that they break the circuit when either of the game's doors is opened, thereby protecting the coin collector from possible injury. These switches are disabled when troubleshooting or adjusting the machine by pulling the white actuator out.

After the interlock switches, both the hot and neutral 117 VAC lines enter the TV monitor. Notice that the monitor is protected by its own separate 0.6 Amp fuse. The primary of the transformer is also protected by a fuse, and in this case it is a 1 Amp Slo-Blo fuse. The Slo-Blo is used for the transformer because a cold transformer draws an unusually high amount of current while warming up. An ordinary fuse would blow at this time, but the Slo-Blo variety will pass a greater amount of current for a short period of time. If the overload continues for too long, however, the fuse will eventually blow and break the circuit. *When replacing fuses, always follow the manufacturer's specifications. Never replace a blown fuse with one having a higher rating and never jump the fuse terminals for any reason.* A machine which repeatedly blows its main fuse cannot be cured by using a higher amperage fuse. This will only aggravate the problem by allowing other, more expensive components to overheat and destroy themselves.

The common side of the coin switch is connected to ground and it normally pulls pin F L0. When the coin is accepted, the switch grounds out pins 5 and E. The deposit of the coin is recorded by the credit flip-flops in the computer and it also lights the credit LED and trips the coin counter.

The PCB is plugged into the edge connector to facilitate replacement. The edge connector in this case is double sided. The numbered pins are on the top and the lettered ones on the bottom. Each letter-number pair are on top of each other and are often used for the same purpose. The pins on the ends of the connector are grounded and this is found in all games. The connection between the edge connector contact and the printed circuit board trace is often the source of problems. To check contact, turn off all power and use a continuity tester from the PCB trace to the lug on the outside of the edge connector. If the connection is discontinuous, check to see if the trace and contact are clean and free of foreign material. If so, lightly bend the edge connector contact down so that it makes contact.

A three wire cable is used to enter the video and audio inputs to the monitor. The wire is grounded to suppress noise. Many recent games use an external speaker in which case there will be a separate wire leading to it.

# CHAPTER III

## MAINTENANCE AND ADJUSTMENTS

### MAINTENANCE

Since video games are designed using solid state circuitry throughout, they require far less maintenance and adjustment than their electromechanical counterparts. Generally speaking, once a game has *burned in* for a few days (all PCBs are pre-burned in at the factory) and all the bugs worked out, it should run perfectly for years with only an occasional bit of attention.

### CLEANING

Game cabinets and glass may be cleaned with any non-abrasive household cleaner. If you wish, special coin machine cleaners which leave no residue are available from your distributor. Do not dry wipe plexiglass, because the dust you are wiping around on the surface will scratch and *fog* the plastic. Any approved glass cleaner can be used on plexiglass.

### LUBRICATION

Lubricate the door locks with WD-40 or graphite at least once every six months. Insert and withdraw the key a few times to work the lubricant around. Spray the coin acceptor lightly with WD-40 every other time the machine is collected. If the game has mechanical controls such as joysticks or foot pedals, these may need periodic lubrication. Consult the game instruction manual for specific details on lubrication points, types of lubricants and the lubrication schedule. *Never lubricate potentiometers in any way.* Any oil or grease which enters a pot will eventually cause it to malfunction. Jerky paddle motion is not caused by a "sticking" pot, but rather by poor contact between the contact arm and the resistance winding of the unit. Replace as necessary.

Inspect the line cord frequently to be sure the insulation is still in good condition. Be sure that the machine is plugged into a grounded receptacle or is connected to a good earth ground in some other way. As an operator, *you* are responsible if any of your clients are injured.

## ADJUSTMENTS

### PCB ADJUSTMENTS

Every game has at least one printed circuit board adjustment. Slide switches are used to condition the game for one or two plays per coin, etc. and are set to the desired position prior to placing the machine on location. See the game instruction manual for specific instructions in this regard.

Other adjustments are accomplished either by moving the position of jumper wires or by turning small blue trim pots. Jumper wire adjustments are only infrequently used and are employed mainly for adjustments which rarely need changing. For example, the race tracks in Gran Trak are changed in this manner and the replay score in Pin Pong is adjusted by moving wires in much the same way the replay score in a pinball machine is adjusted.

Variable adjustments are accomplished by turning trim pots found in the discrete section of the PCB. These pots may be used to adjust play time, paddle travel and other features.

#### PLAY TIME

Play time is adjusted by turning the associated pot until the game ends at the desired point. If in doubt, allow the player a little more for his money than a little less. Nothing infuriates a player more than paying a quarter for thirty seconds of play.

#### PADDLE POSITION

The bottom limit of paddle travel is established by a circuit in the computer. The top of paddle travel is adjustable by turning the associated trim pot. To adjust, turn the player's control so that the paddle is at the extreme top of its travel and adjust the pot so the paddle rests just inside the playfield wall (or the edge of the CRT in games like Pong).

*The importance of properly adjusted paddles cannot be overstressed as a maladjusted paddle will discourage players from continuing to use the machine.*

#### TWO DIMENSIONAL PADDLES

If you have a game which uses a dual-potentiometer joystick to provide omnidirectional paddle motion, use the following procedure. Other games which use this type of control to control different images will have similar adjustment procedures as well.

Adjustment is indicated if the paddle will not travel fully to the boundaries of its court or if it enters the other player's area. Three different adjustments are required for each paddle. Two adjustments (one vertical and one horizontal) are found on the joystick control itself and another vertical adjustment is on the PCB. Each paddle is adjusted separately.

1. First move the joystick to its extreme right hand position and turn the ear of the horizontal adjustment until the paddle is just inside the right limit.
2. Set the joystick to the extreme upper limit and turn the vertical joystick adjustment ear until the paddle is barely below its upper boundary.
3. Adjust the lower limit of paddle travel by turning the trim pot located on the PCB. Set the joystick to the extreme lower position and turn the pot until the paddle is just inside the lower boundary.

If the last adjustment disturbed the upper limit adjustment, it will be necessary to repeat steps 2 and 3 until the proper vertical positioning is achieved. NOTE: Each joystick potentiometer has a physical stop which is pre-adjusted at the factory. The stop has been glued in the proper place and should not be tampered with.

## TV MONITOR ADJUSTMENTS

The TV monitor is adjusted like any normal TV set. If the game has a separate speaker, it is adjusted by a pot on the PCB. Consult the game instruction manual for its location.

1. BRIGHTNESS: Brightness is adjusted *before* contrast. Adjust so that the CRT background is as dark as possible without diminishing the brightness of the video display.
2. CONTRAST: Adjust so that the images are as bright as possible against the pre-adjusted dark background without being blurred.
3. VERTICAL HOLD: Adjust only if the picture appears to be rolling up or down the CRT. Adjust for a stable, centered picture.
4. VERTICAL SIZE: The vertical size and vertical linearity adjustments are interactive. The vertical size adjustment changes the vertical dimension of the picture. Adjust for optimum picture size.

5. VERTICAL LINIARITY: Change this adjustment only if the top of the picture seems *compressed*. If the game is a paddle game, adjust the liniarity so the paddle remains the same size throughout its travel. If not, use some other image to establish if the top of the picture is being compressed. If adjusting the liniarity has adversely affected vertical size, repeat Steps 4 and 5.
6. YOKE: Normally, the yoke should never require adjustment unless the monitor has been installed in a different type of game or the adjusters tampered with. In either case, the entire picture will appear to be offset and normal adjusting will not restore it to its proper position. The two yoke adjusters are located on the rear of the CRT and theu affect the vertical and horizontal deflection of the electron beam. If yoke adjustment is indicated, adjust both yoke rings simultaneously for optimum centering of the picture within the CRT. Generally speaking, yoke adjustment is best handled by qualified personnel, but do not hesitate to become qualified yourself.

## ANTENNA ADJUSTMENTS

The antenna wire connected to pin 6 in Figure 17 is part of the *electronic latch* circuit which prevents players from obtaining free games by inducing a static discharge in the machine. Were it not for this circuit, a static discharge could produce a transient sufficient to toggle the credit flip-flops and provide a free game. The antenna wire picks up part of the discharge when it occurs and breaks the latch which disables game credit. The antenna wire is adjusted normally by trimming it or adding a bit to it. Trimming the wire shorter *decreases* the sensitivity of the circuit. Adding a bit of wire *increases* the sensitivity.

A maladjusted antenna wire can cause its share of strange problems. If the circuit is too sensitive, game credit may be shut off during the progress of a legitimate game; leave the wire too short and you may be giving away free games to all the neighborhood kids.

Some recent games have a pot in addition to the antenna wire and in this case it is the pot which is adjusted. The pot is found on the PCB and it saves trimming the wire and then having to add a bit when you discover from the neighborhood kids that you cut off too much.

# CHAPTER IV

## COMPUTER LOGIC AND DIGITAL DEVICES

It is not within the scope of this handbook to teach an in-depth course in digital theory. The field is quite complex when studied in detail and there are many other books available which do more justice to the subject than we can here in the given amount of space we have. However, we will review the basic principles of digital logic, the nomenclature associated with the devices and the operation of the more common logic circuits. Keep in mind that to successfully repair digital equipment, all you need to know is how the logic circuit *should* work, not *why* it works.

### LOGIC FAMILIES

All digital devices used in Atari video games are of the TTL (Transistor-Transistor Logic, sometimes known as T<sup>2</sup>L) family or are TTL compatible. TTL circuits are identified by a 7400 or 9300 series part number (the 5400 series is used primarily by the military and aerospace industry where greater resistance to radiation and moisture are required). TTL circuits are used because the technology is relatively fast and noise immune and it has been around long enough so that there are a great variety of circuits available at reasonable prices. TTL devices may be used in conjunction with other logic families, if *level shifters* are employed to match up input and output voltage levels.

RTL (Resistor-Transistor Logic) is an ancestor of TTL which was quite widely used in its day. However, due to its low fan-out capability, its relatively low speed (propagation delay: 30 ns), its high noise susceptibility and the fact that it does not readily lend itself to MSI and LSI levels of integration, RTL logic has become obsolete. DTL (Diode-Transistor Logic) has a lower output impedance than RTL, so it has greater fan-out capability. Although propagation delay in DTL is about the same as in RTL, DTL is approximately three times more noise immune. However, even though DTL is relatively noise immune, it is rapidly becoming an extinct family. ECL (Emitter-Coupled Logic) is extremely fast (propagation delays on the order of 3 ns), but it is also very susceptible to noise. ECL is widely used in applications where high speed is a primary concern. CMOS (Complementary Metal Oxide Semiconductor) is a relatively new technology quickly gaining in popularity. Although slower than TTL, CMOS devices are capable of greater size reduction and therefore find acceptance in large integrated circuits.

## INTEGRATION

By "integration" we mean there are a number of components or subcircuits *integrated* into one separate logic circuit or package. Integrated circuits are produced by depositing layers of semiconductor and other materials on silicon chips using photographic processes. The original circuit design may be very large and contain thousands of transistors and other elements. The final chip however is so small that the individual components cannot be seen without the aid of a microscope.

The semiconductor materials are deposited on the chip in a special oven. *Masks* are used to photographically deposit a *resist*. Areas of semiconductor material are then *etched* away by another compound to create regions between materials known as *gates*. Gates have certain electrical properties which allow the implementation of digital theory.

## LEVELS OF INTEGRATION

The scale or *level of integration* of semiconductor devices in the same size package can range from the simplest of devices (i.e. inverters) to extremely complex logic systems. *SMALL SCALE INTEGRATION* (SSI) encompasses the relatively simple devices such as inverters, gates and flip-flops. Since these devices are so simple, they require fewer inputs and outputs, hence there are usually several of them in each package.

*MEDIUM SCALE INTEGRATION* (MSI) is used to describe more complex system built from gates, but providing other functions. Counters, latches, shift registers and multiplexers are all MSI devices. Usually, there is but one MSI device in each 14 or 16 pin DIP.

*LARGE SCALE INTEGRATION* (LSI) is a relatively new field made possible by the advent of CMOS semiconductor technology. Although delicate, CMOS devices are capable of great reduction in size and therefore require less space for a given logic function. LSI chips are not currently used in video games, but the day will no doubt come when much of the common circuitry found on today's PCB will be reduced down to a single LSI chip.

## LOGIC SYMBOLLOGY AND NOTATION

The function and operation of logic circuits is described using standard symbology and notation. All logic functions are described using the *positive logic convention*. Positive logic is a system of notation where the more positive of two levels is called the HI or (1) state and the more negative the LO or (0) state. The specific voltages for HI and LO are +2.4 to +5 VDC for HI and 0 to +0.8 VDC for LO.

Signal names overscored (e.g.  $\overline{\text{START}}$  and pronounced "start not") generally go LO to initiate events (*active LO*), and those not overscored go HI when active. Overscored signals are *always* at the logic level opposite their non-overscored counterparts.

## SIGNAL NAMES

There are no standard conventions for naming signals, so the game designer generally makes up his own. Consequently there is a great diversity in signal naming from game to game. Some signals such as CLOCK, H RESET, V SYNC, etc. remain the same from game to game. Other signal names may be different from game to game even though their function is the same. For example, the signal which enables or disables the game's play mode functions is variously known as ATTRACT, ATTACT, ATTRC, etc. Signal names are often abbreviated such as H SYNC (horizontal synchronization), VLd (vertical load), RST (reset), CLK (clock), VID (video), etc. Signals not easily given meaningful or characteristic names are simply identified by letters and/or numbers. For example, sync chain outputs are known as 1V, 2V, 4V, etc. and ROM outputs may be called  $A^0$ ,  $A^1$ ,  $A^2$  and so on. The letter Q always indicates an output, no matter what the application.

## SCHEMATIC SIGNAL FLOW

A general effort is made to organize schematics so the flow of signal development follows a logic convention. Inputs generally enter the circuit from the left or top and outputs exit the bottom or from the right side. Therefore, signal processing generally proceeds from left to right and top to bottom.

## SCHEMATIC SYMBOLS AND LOCATIONS

The schematic is divided into a grid much like the PCB. When you see an input which bears the note "From C3-2" you know that the circuit which produces this signal is located on the second page of the schematic and at the intersection of the C column and third row.

Figure 19 illustrates some of the more important conventions used in drawing schematic symbols.

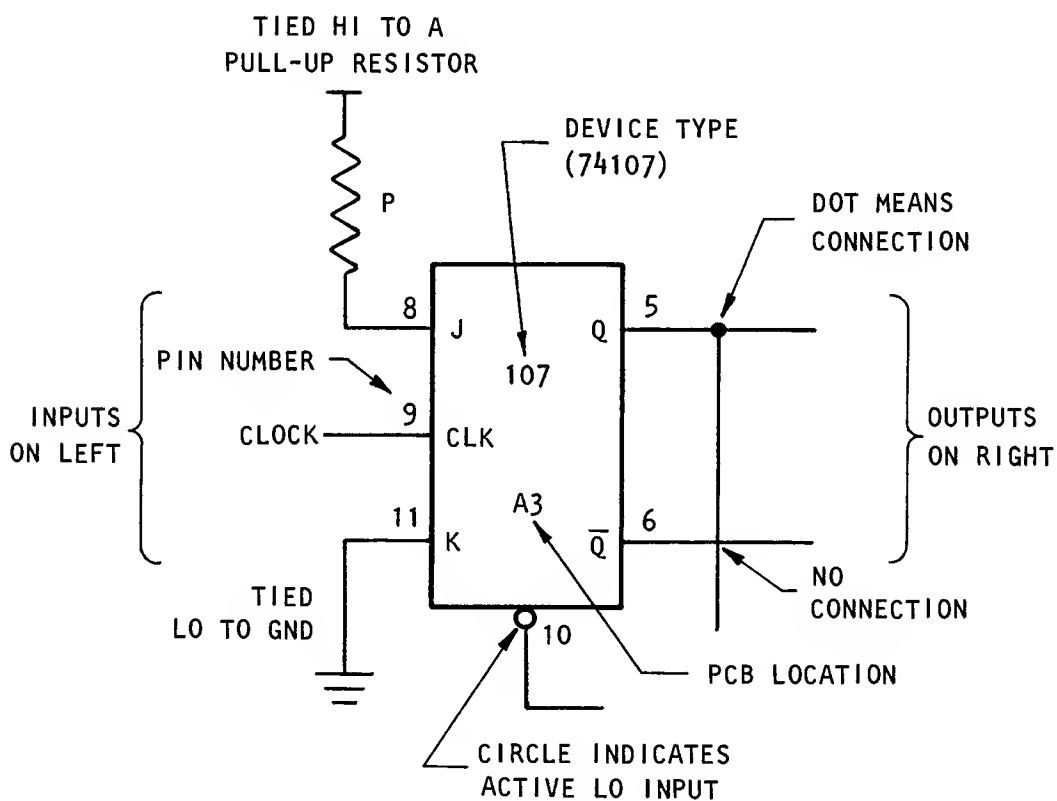


FIGURE 19  
SCHEMATIC SYMBOL CONVENTIONS

## THE BINARY COUNTING SYSTEM

Everybody is familiar with the decimal counting system, because it is the one we normally use every day. Moreover, this system developed because of the fact that we humans have ten fingers or *digits*. Logic circuits, however, have only two "fingers": on and off. Therefore, all logic devices count by 2s instead of 10s. This counting method takes a bit of practice getting used to, but it is by no means difficult.

In the decimal system, each *place* contains successively higher multiples of ten. The first place is the 1s place or  $10^0$  (any number raised to the zero power is 1). The second place is the 10s place or  $10^1$  ( $1 \times 10$ ). The third is for 100s or  $10^2$  ( $10 \times 10$ ), and so on. The number 256 consists of 2 in the 100s place (or 200), 5 in the 10s place (or 50) and 6 in the 1s place (or 6). The addition of these numbers is 256.

	$10^2$	or 100s
	—	
	$10^1$	or 10s
	—	
	$10^0$	or 1s
	—	
2	5	6

$$200 + 50 + 6 = 256$$

FIGURE 20  
DECIMAL SYSTEM EXAMPLE

The binary system is similar except that each place contains multiples of *two* instead of ten. The first place is the 1s place or  $2^0$ . The second is the 2s place or  $2^1$  ( $1 \times 2$ ). The third is the 4s place or  $2^2$  ( $2 \times 2$ ). The fourth is the 8s place or  $2^3$  ( $2 \times 2 \times 2$ ).

Figure 21 illustrates the binary count up to the decimal number 16. The first number, zero, has no value so "0" appears in all the places. The decimal number 1 is expressed in binary by 0 0 0 0 1 (a 1 in the 1s place). The number 2 is 0 0 0 1 0 (a 1 in the 2s place). Three is the addition of 1 and 2 or 0 0 0 1 1.

When dealing with digital devices, each numeral is called a *bit*. The entire number is known as a *word*. Looking at Figure 21, you can see that it takes only one bit to express the number 1, two bits for 2 and 3, three bits for numbers 4 through 7 and four bits for 8 through 15. A fifth bit is required to express the number 16. Each bit is a higher power of 2. Numbers greater than nine bits are rarely used in video games, because, generally speaking, 454 is the highest number needed. If nine bits are used, numbers as large as 1 1 1 1 1 1 1 1 1 (or 511) can be expressed.

Although we humans can count and express numbers by using numerals, computers use L0 (voltage) for 0 and H1 (voltage) for 1. In a moment, we will see how a binary counter chip can count from 0 0 0 0 to 1 1 1 1 at its four output pins by sequentially producing H1s and L0s at the appropriate pins. But in the meantime, we must first discuss the more basic digital devices.

Decimal	$2^4$ (16)	$2^3$ (8)	$2^2$ (4)	$2^1$ (2)	$2^0$ (1)
0	0	0	0	0	0
1	0	0	0	0	1
2	0	0	0	1	0
3	0	0	0	1	1
4	0	0	1	0	0
5	0	0	1	0	1
6	0	0	1	1	0
7	0	0	1	1	1
8	0	1	0	0	0
9	0	1	0	0	1
10	0	1	0	1	0
11	0	1	0	1	1
12	0	1	1	0	0
13	0	1	1	0	1
14	0	1	1	1	0
15	0	1	1	1	1
16	1	0	0	0	0

FIGURE 21  
BINARY SYSTEM TRUTH TABLE

## THE BASIC DIGITAL LAWS

All logic devices and circuits are constructed from three basic building blocks which are governed by these laws: *and*, *or* and *negation*. The first law states that when two signals are ANDed together, the output is H1 only when *both* inputs are H1. The OR principle states that the output will be H1 when *either or both* inputs are H1. A variation of the OR theme is the exclusive OR. In this case, the output is H1 when either, *but not both*, input signals are H1. Negation simply means that the output is always *inverted* to the logic level opposite the input.

## ACTIVE HI VS ACTIVE LO

It is easier to understand circuits where signals go HI to initiate events, however the active LO system is more flexible. Consequently, most MSI chips are provided with active LO control inputs. Since active LO control inputs are so prevalent, many chips also have inverted outputs so that most MSI devices are directly compatible. Active LO inputs and inverted outputs are indicated by an empty circle at the appropriate pin. If the chip does not have inverted outputs, or if an active HI signal must be used in an active LO input, an external inverter is employed to provide the inverse of the signal.

Internal inverters are used for the outputs of AND and OR gates to provide the inverse functions NAND (Not AND) and NOR (Not OR).

## MATHEMATICAL NOTATION

Since signals are sometimes named using their mathematical expressions, we are including an explanation of this system of notation. However, the major use for this notation is in logic design, where the mathematical expressions are used to solve equations and determine circuit configurations.

Using this notation,  $(\cdot)$  indicates the AND operation,  $(+)$  denotes the OR function and  $(\oplus)$  indicates the exclusive OR operation. The logic of an AND gate is expressed by  $A \cdot B = Y$  where A and B are the inputs and Y is the output. OR gate logic is expressed by  $A + B = Y$ . For example, when 32H is ORed with 64H, the resulting signal may be denoted on the schematic by  $32H + 64H$ .

## TIMING DIAGRAMS

Timing diagrams are often used to illustrate the timing relationships between signals as they are processed by the computer. These diagrams are especially useful where the developmental process is more complicated than the simple gating together of two signals. Also, timing diagrams simulate the appearance of the waveforms on an oscilloscope which facilitates troubleshooting the circuit with a scope.

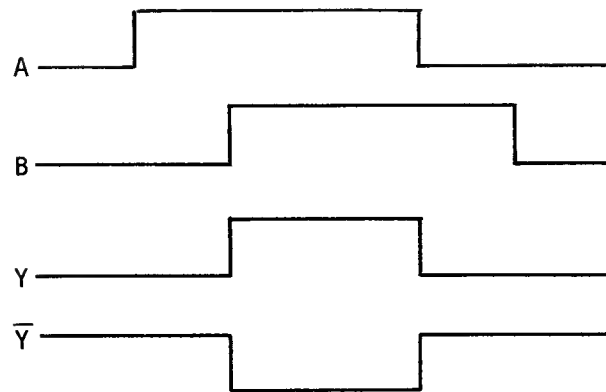


FIGURE 22  
AND and NAND LOGIC

Figure 22 illustrates AND and NAND logic. You can see that the ANDed output pulse Y is HI only during the time period when both the A and B inputs are HI. Since the NAND gate produces the inverse function, its output  $\bar{Y}$  is always at the opposite logic level.

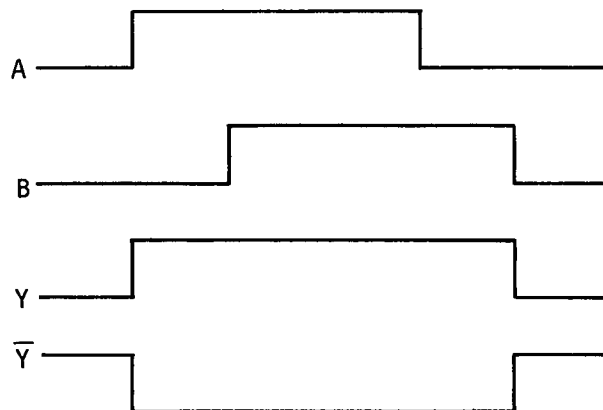


FIGURE 23  
OR and NOR LOGIC

Figure 23 illustrates OR and NOR logic. The output signal Y is HI only when A and/or B is HI.

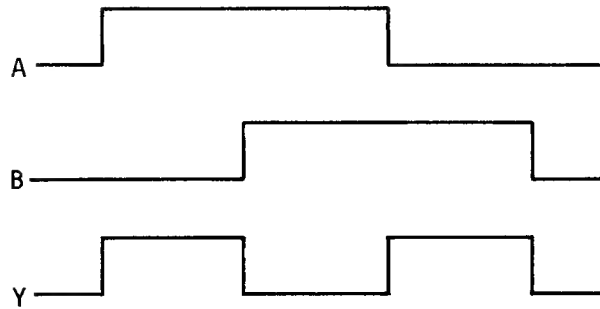


FIGURE 24  
EXCLUSIVE OR LOGIC

Figure 24 illustrates the logic of the exclusive OR. The output is identical to the OR output except during the time when both signals are HI.

## WAVEFORM NOMENCLATURE

Waveforms have a few characteristics which need mentioning and these are illustrated in Figure 25. The *pulse* is that period of time in which the signal is active. The term *duration* denotes how long the pulse is active. *Frequency* refers to the rate at which the pulses occur. *Period* indicates the time between the rising edge of one pulse and the rising edge of the next. The *duty cycle* is the ratio of on-time to off-time. When discussing events initiated by CLOCK, a particular timing notation is used. For example,  $t_n$  refers to the first clock pulse and  $t_{n+1}$  refers to the second clock pulse. The *leading* or *rising* edge is that part of the waveform which goes from the L0 level to the HI level. The *trailing* or *falling* edge is that section which goes from HI to L0. The term *risetime* denotes the amount of time required to make the transition. Devices may be either *rising* or *falling edge triggered* which means that the event occurs on the rising or falling edge of CLOCK.

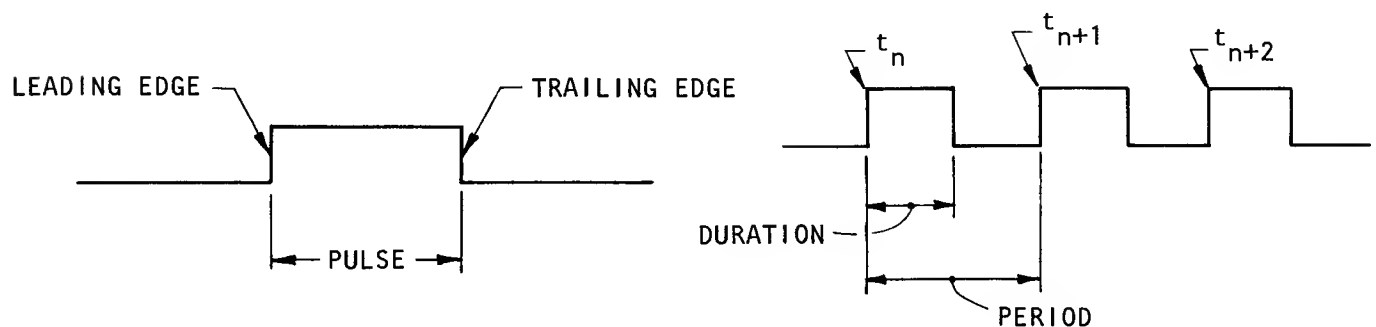


FIGURE 25  
WAVEFORM NOMENCLATURE

## COMMON DEVICE INFORMATION

The following pages contain information regarding specific 7400 and 9300 devices commonly used in video games. This information is not intended to replace the manufacturer's data books. It is included only for orientation purposes. Also, not all the devices used in video games are included in this section. This being true, it would be wise to start your own library of data books. Most manufacturers will send the data books free of charge, especially if you write on company letterhead. Of all the books listed in the following bibliography, National's books are probably the most complete.

Fairchild Semiconductor, Inc.  
Mountain View, Ca.  
TTL Data Book

National Semiconductor Corp.  
Santa Clara, Ca.  
Digital Integrated Circuits

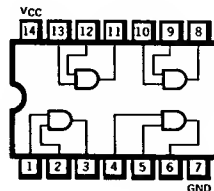
Texas Instruments, Inc.  
Dallas, Tex.  
TTL Data Book

Signetics Corporation  
Sunnyvale, Ca.  
Digital, Linear, MOS

Most manufacturers describe their linear devices in separate books, so you might ask for these as well.

## AND GATES

Several types of AND gates are frequently used, but they differ only in the number of inputs and in the number of devices per package. For example, the 7408 is a quad two-input AND which means there are four AND gates in each package and each gate has two inputs. In comparison, the 7411 (not included) is a triple three-input AND gate package. Since there are more input pins, the 7411 can only accomodate three devices in a 14 pin package. AND gates are available with up to eight inputs.

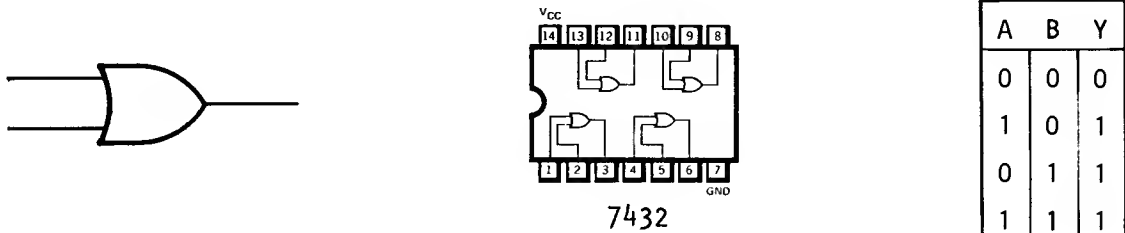


7408

A	B	Y
0	0	0
1	0	0
0	1	0
1	1	1

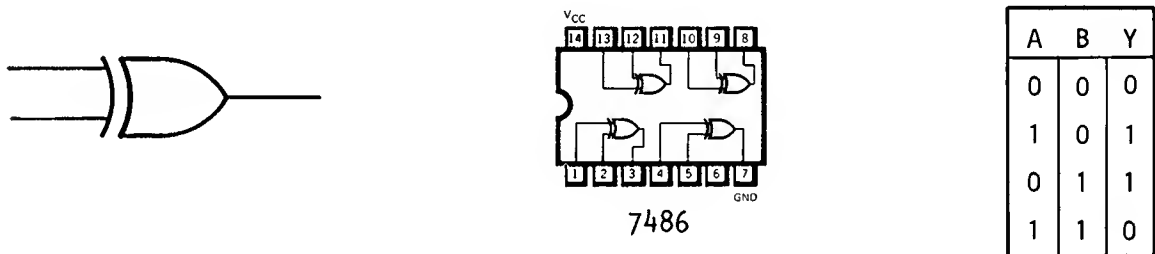
## OR GATES

Although theoretically important, OR gates are not frequently used as active LO logic is more prevalent. Consequently, many NOR varieties are used to the exclusion of the ORs. However, we have included the OR truth table below to familiarize you with its operation.



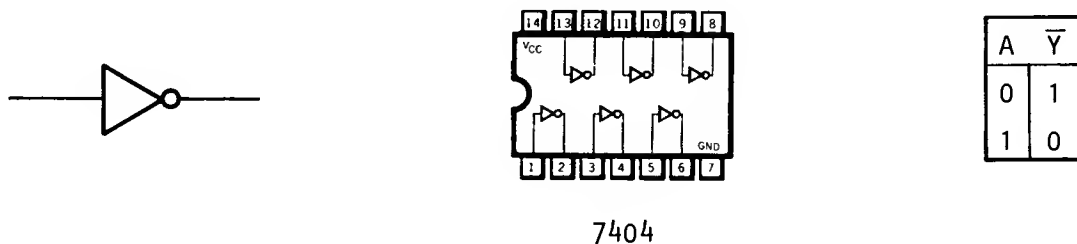
## EXCLUSIVE OR GATES

This gating scheme is used extensively in video games and the 7486 contains four of these devices.



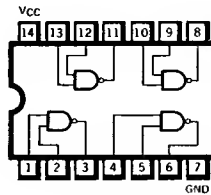
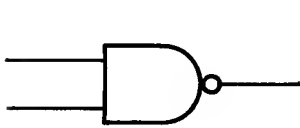
## INVERTERS

Inverters produce the negation function. Since the circuit requires only one input and one output, there are six in each 14 pin package (the other two pins are used for Vcc and GND).



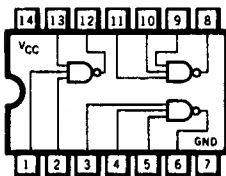
## NAND GATES

As the name implies, the NAND is simply an AND circuit with an inverted output. The prevalence of active LO logic has resulted in a wide variety of NAND gates which differ only in the number of inputs and devices per package. Although not included here, the 7410 and 7420 are also frequently used.

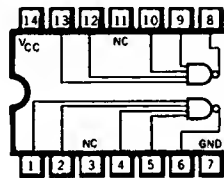


7400

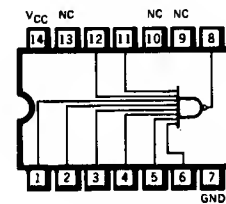
A	B	$\bar{Y}$
0	0	1
1	0	1
0	1	1
1	1	0



7410



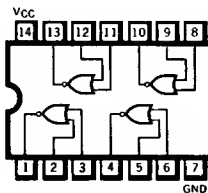
7420



7430

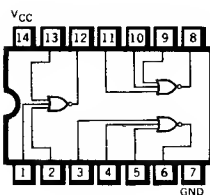
## NOR GATES

The NOR produces the inverse function of the OR.

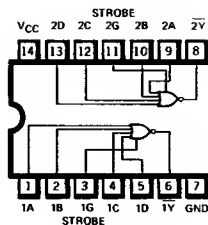


7402

A	B	$\bar{Y}$
0	0	1
1	0	0
0	1	0
1	1	0



7427



7425

## MORE COMPLICATED DEVICES

All the foregoing devices have been simple gates which are easy to understand. Every other digital device -no matter how complex it may seem at first- is nothing more than a number of these gates wired together to produce a particular function. Most of the more complicated devices in the following pages are symbolized only by a "black box" -a rectangle with input and output pins. The actual logic diagrams showing the individual gates can be found in the manufacturer's data book.

## CLOCK INPUTS

CLOCK is the master timing signal for the entire computer and it is a 7 MHz square wave. The clock input pin on the device is an *enable* which is used to time the operations of all CLOCK-connected devices together. Devices connected in this way are said to be operated *synchronously*. Asynchronous operation is also frequently used and other pins (such as *preset* and *clear* in flip-flops and *count enable* in counters) are used to allow events to begin or end. Bear in mind, however, that a device may be clocked by signals other than CLOCK depending on the desired logic characteristics.

## AND/OR INVERT GATES

When wired in this configuration, A and B *and/or* C and D must be HI for the output to be LO. AND/OR invert gates are often used as *selective inverters*. Pong, for example, uses these gates to selectively invert the binary motion codes.

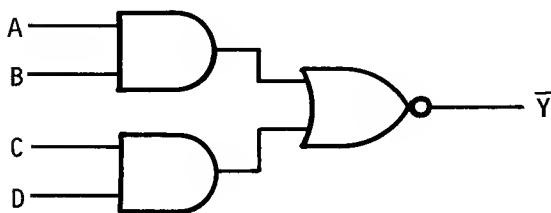
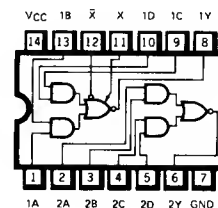


FIGURE 26  
AND/OR INVERT GATE



7450

## FLIP-FLOPS

Flip-flops are such important devices because they can store information. Flip flops are made up of the basic gates arranged in different ways to provide a number of different storage functions. Flip-flops may be used by themselves to store information or in other devices. Counters, latches and shift registers are all constructed from flip-flops.

### R-S FLIP-FLOP

A simple R-S flip flop can be constructed from two NAND gates as illustrated in Figure 27. If R is HI and S is L0, Q will be L0 and  $\bar{Q}$  HI. If S changes, the outputs remain the same. In other words, the circuit has stored the last information (the L0 at S).

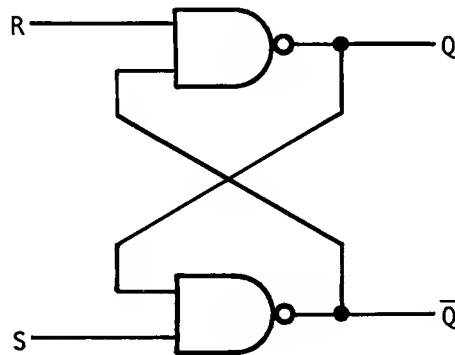
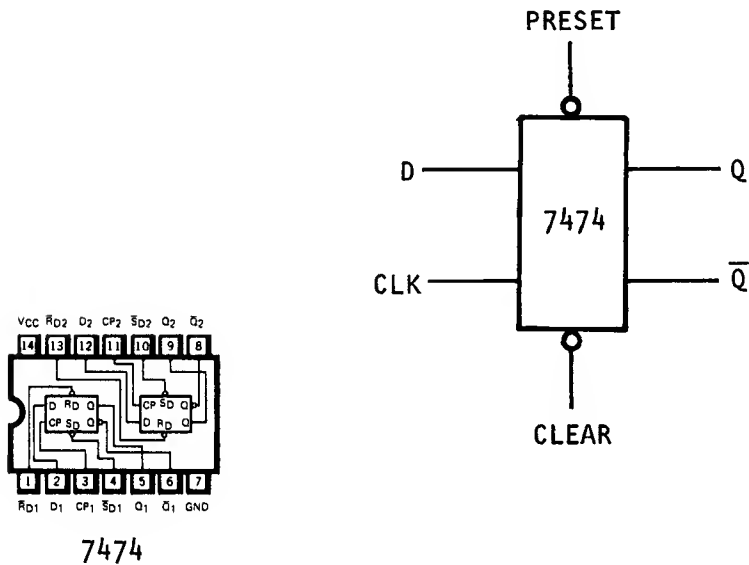


FIGURE 27  
R-S FLIP-FLOP

## D TYPE FLIP-FLOP

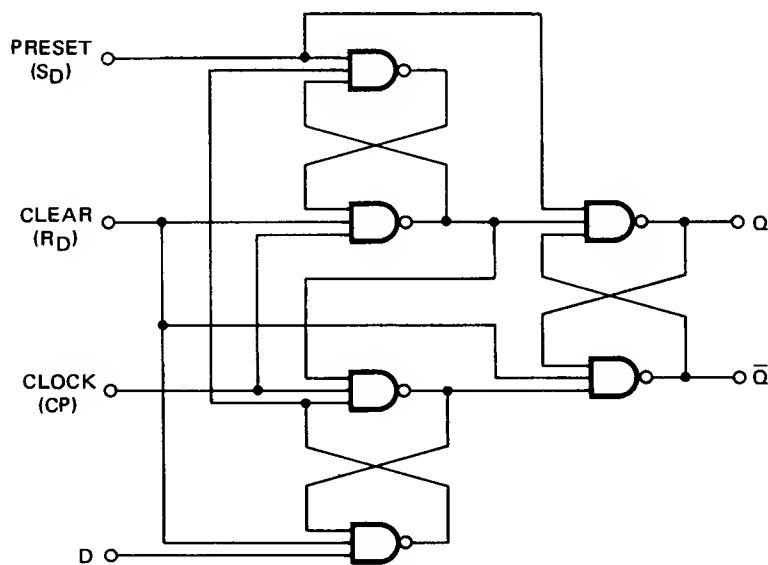
In this case, the information at the D input is transferred to the outputs when the clock pulse goes HI. A L0 input at the preset causes Q to go HI. A L0 at the clear produces a L0 from Q. The  $\bar{Q}$  output is always at the logic level opposite the Q output.



$t_n$	$t_{n+1}$	
INPUT	OUTPUT	OUTPUT
D	Q	$\bar{Q}$
L	L	H
H	H	L

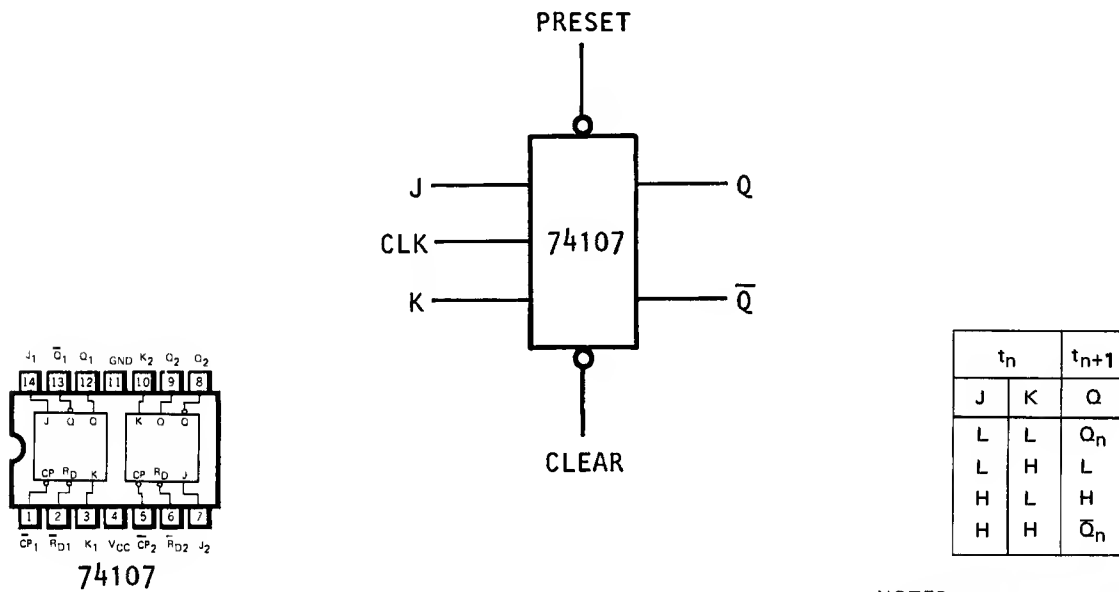
NOTES:

$t_n$  = bit time before clock pulse.  
 $t_{n+1}$  = bit time after clock pulse.

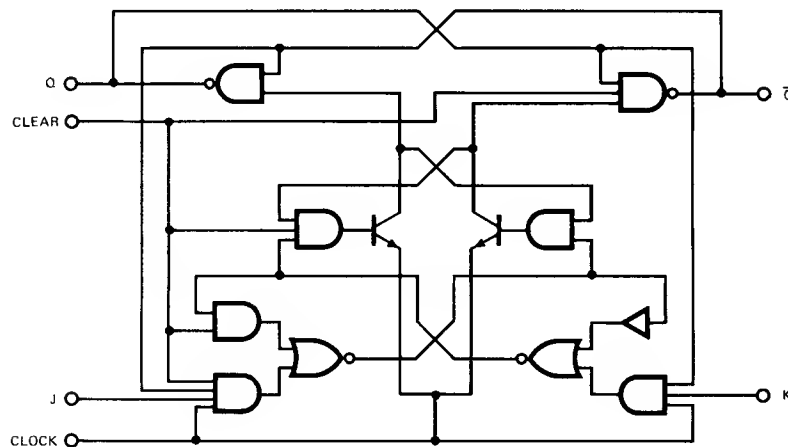


## J-K FLIP-FLOP

If both the J and K inputs are L0 (or HI), the Q (or  $\bar{Q}$ ) output remains at the previous state (or at the inverse of the previous state for  $\bar{Q}$ ). If the J and K inputs are at opposite levels, the Q and  $\bar{Q}$  outputs will reflect those levels when it receives a clock pulse. The preset and clear inputs have the same functions as in the D type flip-flop.



NOTES:  
 $t_n$  = Bit time before clock pulse.  
 $t_{n+1}$  = Bit time after clock pulse.



## MSI DEVICES

All the devices discussed up to this point are relatively simple and fall into the SSI category. Since they are so small, there are several to each package. The following devices, although constructed from gates and flip-flops, produce more complicated functions. These MSI chips have larger circuits with more input and output pins so there is usually only one per package. Sometimes, an especially large circuit will require a 16 pin package. The following circuits produce a wide variety of signal processing functions.

## COUNTERS

The use of integrated counter chips is widespread throughout the PCB circuitry. The counter chip functions by adding or counting clock pulses to form a binary code or number at the outputs. A binary number such as 0 1 0 1 (5) is expressed by L0 H1 L0 H1 at the four counter outputs. Counters are always found in the sync and motion circuits and are frequently used in other circuits as well. All counters used in video games are four-bit counters, which means they count from 0 0 0 0 (0) to 1 1 1 1 (15). If larger numbers are needed, more bits are added.

If only one or two extra bits are needed, flip-flops can be used to extend the four-bit counter to five or six bits. Another counter can be used to provide four extra bits. Counters connected together in this way form *counter chains*. Most counters are used in the synchronous mode, although asynchronous operation is possible and used for applications such as score counting. Mode selection is accomplished by tying various enable pins H1 or L0.

Counters may count in straight binary (0-15) or in BCD (Binary Coded Decimal), in which case it counts in *decades* (0-9).

A simple counter can be constructed from four flip-flops as illustrated in Figure 28. The device counts clock pulses and the flip-flops remember the last number or count. Each successive clock pulse is added to the rest and then that number is stored.

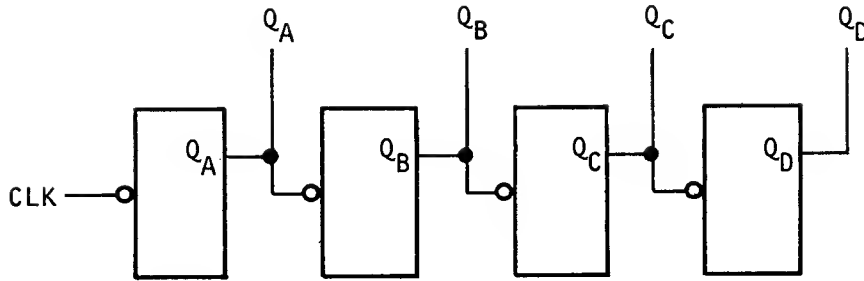


FIGURE 28  
A SIMPLE COUNTER

Before the counter begins, its outputs are all L0 (0 0 0 0). On the falling edge of the first clock pulse,  $Q_A$  goes HI (0 0 0 1) and stays HI until the next rising edge. At this point  $Q_A$  drops L0 producing a HI from  $Q_B$  on the second clock pulse (0 0 1 0). Both  $Q_A$  and  $Q_B$  are HI on the third clock pulse (0 0 1 1). On the fourth clock pulse,  $Q_A$  and  $Q_B$  drop L0 simultaneously causing  $Q_C$  to go HI (0 1 0 0).  $Q_C$  changes every fourth clock pulse and since  $Q_D$  divides this frequency in half,  $Q_D$  changes every eighth clock pulse. On the 15th count all the outputs are HI (1 1 1 1). They return L0 on the 16th or 0 count.

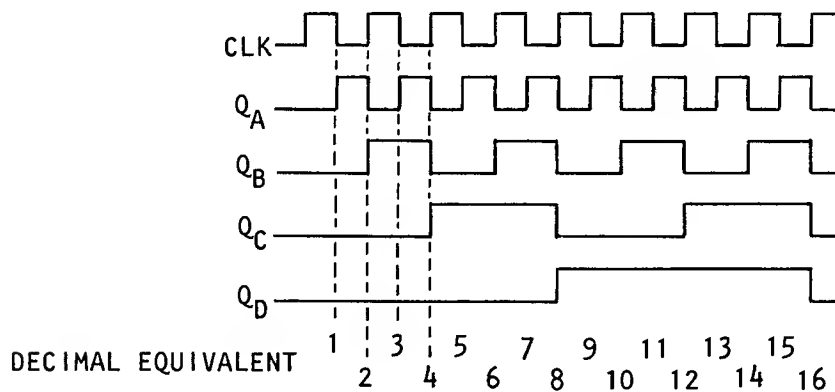


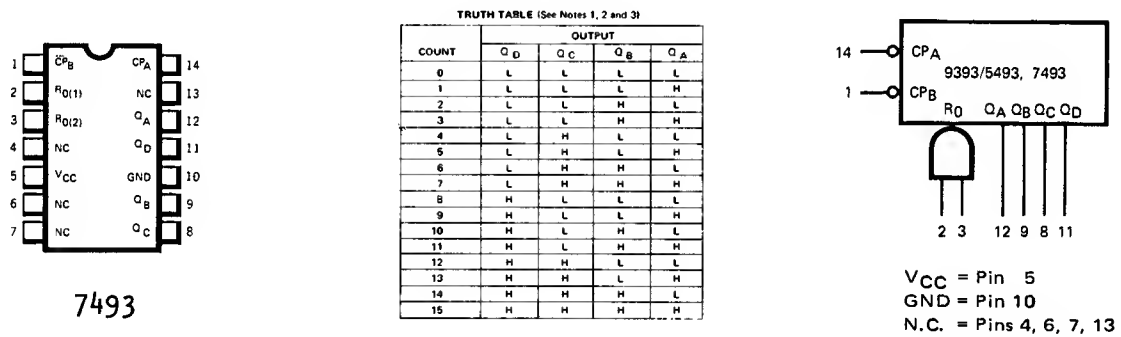
FIGURE 29  
COUNTER OUTPUT WAVEFORMS

## 7493 FOUR BIT BINARY COUNTER

This four-bit binary counter is constructed almost identically to Figure 28. Its major use is in the sync chains. In the logic diagram below, notice that two clock inputs are provided so that the device can be used as a divide-by-two and a divide-by-eight simultaneously. Normally, it is wired as a divide-by-sixteen by connecting pin 1 ( $\overline{CP}_B$ ) to pin 14 ( $\overline{CP}_A$ ).

When the reset input goes LO, all the outputs are reset back to 0 0 0 0. Two reset pins are provided (and internally NANDed) so that counters in a chain may be selectively reset. Normally, both reset pins are tied together.

The 7492 counter is similar, except that it is a simultaneous divide-by-two and divide-by-six which can be wired as a divide-by-twelve.



## 9316 PRESETTABLE BINARY COUNTER

This device is similar to the 7493 except that the count can be preset and started from a desired number by entering the binary code for the preset number at the parallel inputs ( $P_0$ - $P_3$ ). The number is loaded when  $\overline{PE}$  is L0 and the device begins counting when  $\overline{PE}$  goes HI. The counter will count from 0 (or any other number) to 15. The 9310 is the BCD version of the 9316. The 9316 is important because it is found in all motion circuits.

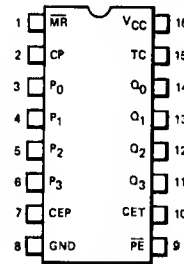
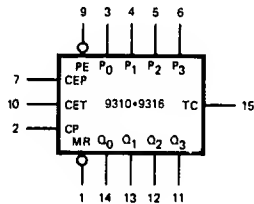
### PIN NAMES

$\overline{PE}$	Parallel Enable (Active LOW) Input
$P_0, P_1, P_2, P_3$	Parallel Inputs
CEP	Count Enable Parallel Input
CET	Count Enable Trickle Input
CP	Clock (Active HIGH Going Edge) Input
$\overline{MR}$	Master Reset (Active LOW) Input
$Q_0, Q_1, Q_2, Q_3$	Parallel Outputs
TC	Terminal Count Outputs

### MODE SELECTION

$\overline{PE}$	CEP	CET	MODE
L	L	L	Preset
L	L	H	Preset
L	H	L	Preset
L	H	H	Preset
H	L	L	No Change
H	L	H	No Change
H	H	L	No Change
H	H	H	Count

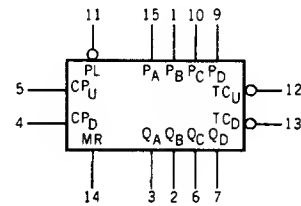
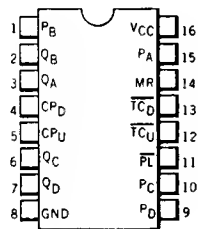
( $\overline{MR}$  = HIGH)



9316

## 74193 UP/DOWN BINARY COUNTER

This counter is also presettable, however the number is loaded asynchronously. In addition, it can count down from the preset number as well as up. The direction of counting is controlled by which clock input is pulsed while the other is held HI. The MR pin is the reset input and is used for asynchronous reset. The binary number is loaded while  $\overline{PL}$  (Parallel Load) is LO and the counting process can begin only when  $\overline{PL}$  goes HI. The 74193 is not a commonly used device, but it is occasionally found in such applications as the Gran Trak steering logic. The 74192 is the BCD counterpart of the 74193.



74193

### MODE SELECTION

MR	$\overline{PL}$	$CP_U$	$CP_D$	MODE
H	X	X	X	Preset (Asyn.)
L	L	X	X	Preset (Asyn.)
L	H	H	H	No Change
L	H	CP	H	Count Up
L	H	H	CP	Count Down

H = HIGH Voltage Level

L = LOW Voltage Level

X = Don't Care Condition

CP = Clock Pulse

### PIN NAMES

$\overline{PL}$

$P_A, P_B, P_C, P_D$

$CP_U$

$CP_D$

MR

$Q_A, Q_B, Q_C, Q_D$

$\overline{TC_U}$

$\overline{TC_D}$

Parallel Load (Active LOW) Input

Parallel Data Inputs

Count Up Clock Pulse Input

Count Down Clock Pulse Input

Master Reset (Clear) Input

(Asynchronous)

Counter Outputs

Terminal Count Up (Carry) Output

Terminal Count Down (Borrow) Output

## MULTIPLEXERS

The multiplexer (often abbreviated as MUX) is a circuit used to select desired signals from a number of other signals. The state of the data select lines determine which signals at the inputs appear at the output.

A simple two-to-one data multiplexer can be constructed from a few gates as illustrated below. A and B are the data-carrying lines and S is the data select. When S is HI, the top gate is enabled, and the A signal will appear at the Y output. Since S is inverted, the HI at S will also disable the lower gate, preventing signal B from getting through. However, when S drops LO, the lower gate is enabled and the data on B will appear at the output.

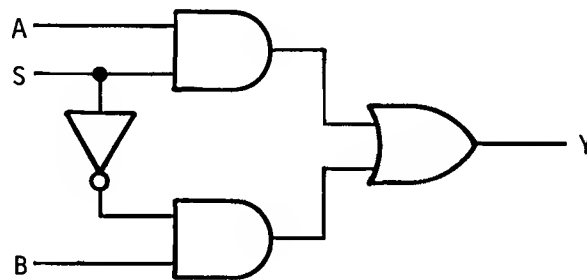
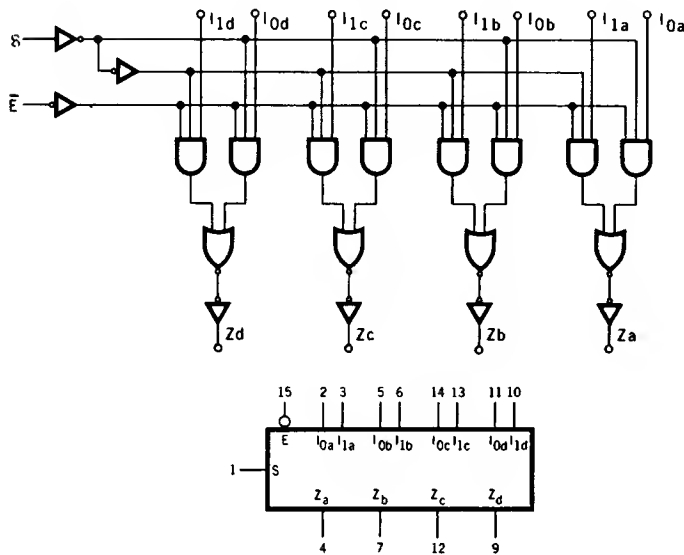


FIGURE 30  
THE BASIC MULTIPLEXER

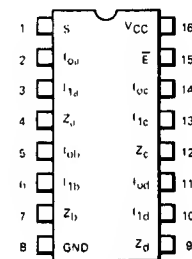
Other multiplexers are merely elaborations of this theme. A four-to-one multiplexer has four input signals, so the select must be able to count from 0 0 (0) to 1 1 (3). Therefore, two select lines are provided: one for each of two bits. Similarly, an eight input multiplexer must have three selects.

## 74157 QUAD 2-TO-1 MULTIPLEXER

This circuit is identical to Figure 30 except there are four of them per package. Note that the enable is active L0.



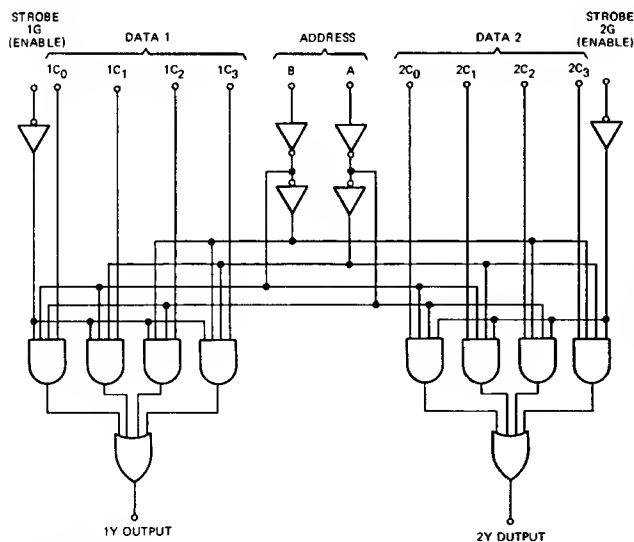
ENABLE	SELECT INPUT	INPUTS		OUTPUT
$\bar{E}$	S	$I_{0X}$	$I_{1X}$	$Z_X$
H	X	X	X	L
L	H	X	L	L
L	H	X	H	H
L	L	L	X	L
L	L	H	X	H



74157

## 74153 DUAL 4-TO-1 MULTIPLEXER

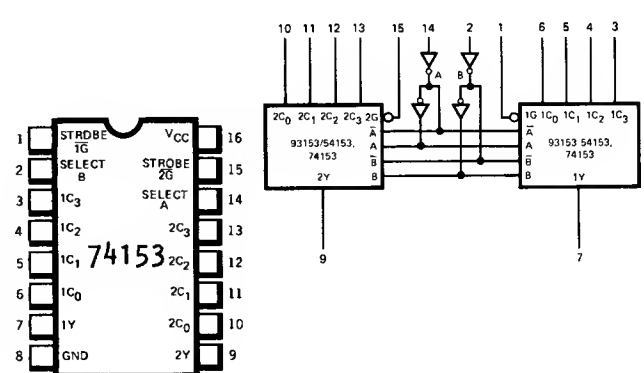
This is similar to the simple multiplexer except that any one of four inputs can be selected. You can see from the truth table that when both selects (A and B) are L0, input  $C_0$  is selected. When A and B are both H1, the fourth input ( $C_3$ ) appears at the output. The strobe input is basically another word for the enable.



### PIN NAMES

1G, 2G, 1C<sub>0</sub>-3, 2C<sub>0</sub>-3, A, B  
1Y, 2Y

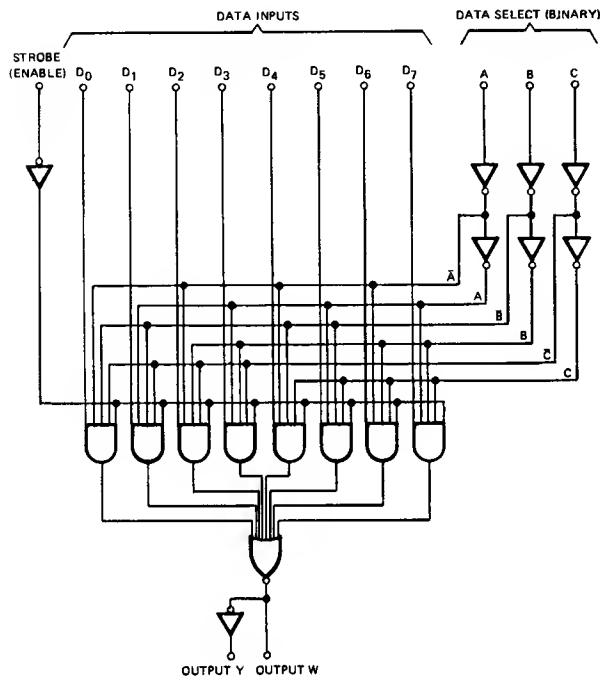
Inputs  
Outputs



ADDRESS INPUTS		DATA INPUTS				STROBE	OUTPUT
B	A	C <sub>0</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	G	Y
X	X	X	X	X	X	H	L
L	L	L	X	X	X	L	L
L	L	H	X	X	X	L	L
L	H	X	L	X	X	L	L
L	H	X	H	X	X	L	L
H	L	X	X	L	X	L	L
H	L	X	X	H	X	L	L
H	H	X	X	X	L	L	L
H	H	X	X	X	H	L	H

## 74151 & 74150 8-TO-1 & 16-TO-1 MULTIPLEXERS

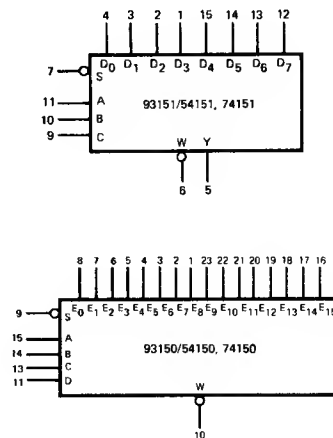
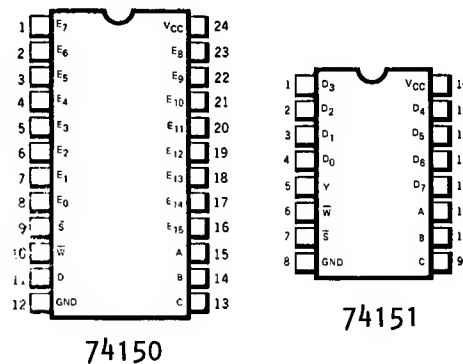
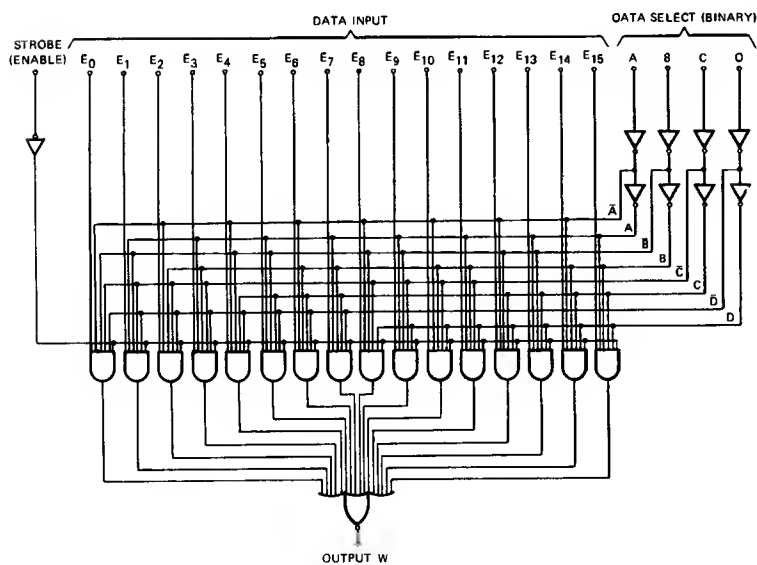
Since there are more inputs to these devices, only one will fit in each package. The 74151 can select one of eight inputs so there must be three selects, as three bits are required to count up to eight. Likewise, the 74150 must have four selects. Note that the 74150 is in a 24 pin package.



		INPUTS								OUTPUTS	
C B A	STROBE(1)	D <sub>0</sub>	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	D <sub>5</sub>	D <sub>6</sub>	D <sub>7</sub>	Y(1)	W
X	X	X	L	X	X	X	X	X	X	L	H
L	X	L	L	X	X	X	X	X	X	L	H
L	L	L	L	X	X	X	X	X	X	H	L
L	L	L	H	L	X	X	X	X	X	L	H
L	L	L	L	X	H	X	X	X	X	H	L
L	L	L	L	X	X	L	X	X	X	L	H
L	L	H	L	X	X	H	X	X	X	H	L
L	H	H	L	X	X	X	L	X	X	L	H
L	H	H	L	X	X	X	H	X	X	H	L
H	L	L	L	X	X	X	X	L	X	L	H
H	L	L	L	X	X	X	H	X	X	H	L
H	L	H	L	X	X	X	X	H	X	L	H
H	H	L	L	X	X	X	X	L	X	H	L
H	H	L	L	X	X	X	X	X	X	L	H
H	H	H	L	X	X	X	X	X	X	H	L
H	H	H	H	X	X	X	X	X	X	H	H

NOTES:

1. 64151, 74151 only.
2. When used to indicate an input, X = Irrelevant.

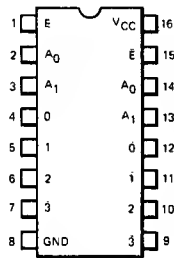


## DECODERS

Decoders are basically reverse multiplexers. With this type of device a single input signal can be routed to any output. Decoders are provided with active L0 outputs to facilitate addressing other MSI devices equipped with active L0 inputs. Decoders are used to demultiplex information in various circuits and to generate 7-segment numeral displays in score display circuits.

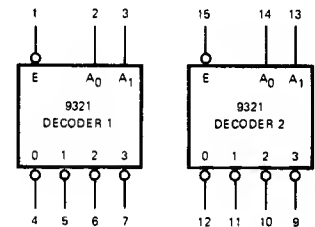
### 9321 1-OF-8 DECODER

The information to be decoded is entered at the enable inputs which are normally tied together. The binary code at the address inputs selects which output will reflect the input information.



9321

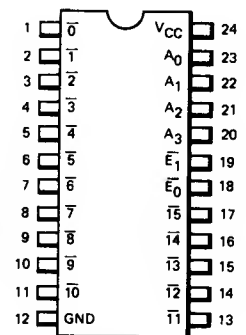
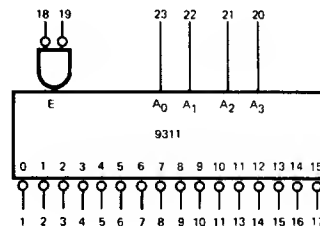
$\bar{E}$	$A_0$	$A_1$	$\bar{0}$	$\bar{1}$	$\bar{2}$	$\bar{3}$
L	L	L	L	H	H	H
L	H	L	H	L	H	H
L	L	H	H	H	L	H
L	H	H	H	H	H	L
H	X	X	H	H	H	H



### 9311 1-OF-16 DECODER

This device is similar to the 9321 except one of sixteen outputs is selected.

$\bar{E}_0$	$\bar{E}_1$	$A_0$	$A_1$	$A_2$	$A_3$	$\bar{0}$	$\bar{1}$	$\bar{2}$	$\bar{3}$	$\bar{4}$	$\bar{5}$	$\bar{6}$	$\bar{7}$	$\bar{8}$	$\bar{9}$	$\bar{10}$	$\bar{11}$	$\bar{12}$	$\bar{13}$	$\bar{14}$	$\bar{15}$
H	H	X	X	X	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
H	L	X	X	X	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	H	X	X	X	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H



9311

#### PIN NAMES

$A_0, A_1, A_2, A_3$

$\bar{E}_0, \bar{E}_1$

$\bar{0}$  to  $\bar{15}$

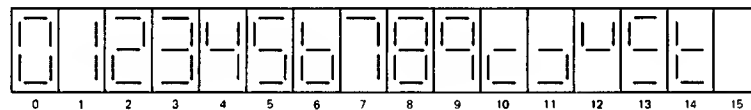
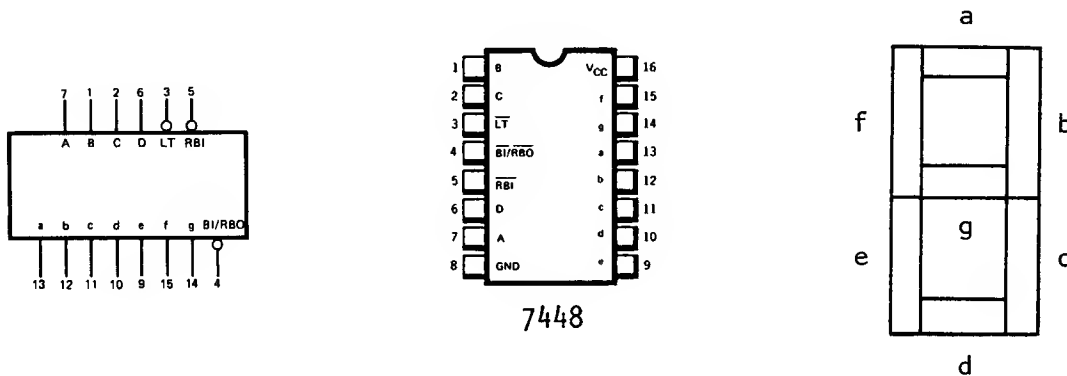
Address Inputs

AND Enable (Active LOW) Inputs

(Active LOW) Outputs (Note b)

## 7448 BCD TO 7-SEGMENT DECODER

A seven segment display consists of an LED arrangement or a multiplexed video display where various segments are "turned on" to reveal decimal numerals. The 7-segment decoder accepts BCD information at its A, B, C and D inputs and outputs the signals needed to turn on the various segments at outputs a through g. For example, the number 9 is expressed in binary by 1 0 0 1. If this code is entered at the BCD inputs, outputs a, b, c, f and g will go HI and illuminate the a, b, c, f and g segments.



NUMERICAL DESIGNATIONS – RESULTANT DISPLAYS

DECIMAL OR FUNCTION	INPUTS						OUTPUTS								NOTE
	$\overline{LT}$	$\overline{RBI}$	D	C	B	A	$\overline{BI/RBO}$	a	b	c	d	e	f	g	
0	H	H	L	L	L	L	H	H	H	H	H	H	L	L	1
1	H	X	L	L	L	H	H	L	H	H	L	L	L	L	1
2	H	X	L	L	H	L	H	H	H	L	H	H	L	H	
3	H	X	L	L	H	H	H	H	H	H	H	L	L	H	
4	H	X	L	H	L	L	H	L	H	H	L	L	H	H	
5	H	X	L	H	L	H	H	H	L	H	H	L	H	H	
6	H	X	L	H	H	L	H	L	L	H	H	H	H	H	
7	H	X	L	H	H	H	H	H	H	H	L	L	L	L	
8	H	X	H	L	L	L	H	H	H	H	H	H	H	H	
9	H	X	H	L	L	H	H	H	H	H	L	L	L	H	
10	H	X	H	L	H	L	H	L	L	L	H	H	L	H	
11	H	X	H	L	H	H	H	L	L	H	H	L	L	H	
12	H	X	H	H	L	L	H	L	H	L	L	L	H	H	
13	H	X	H	H	L	H	H	H	L	L	H	L	H	H	
14	H	X	H	H	H	L	H	L	L	L	H	H	H	H	
15	H	X	H	H	H	H	H	L	L	L	L	L	L	L	
$\overline{BI}$	X	X	X	X	X	X	L	L	L	L	L	L	L	L	2
$\overline{RBI}$	H	L	L	L	L	L	L	L	L	L	L	L	L	L	3
$\overline{LT}$	L	X	X	X	X	X	H	H	H	H	H	H	H	H	4

### NOTES:

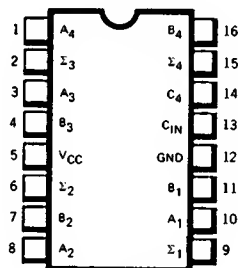
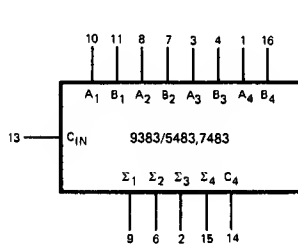
- (1)  $\overline{BI}/\overline{RBO}$  is wired-AND logic serving as blanking input ( $\overline{BI}$ ) and/or ripple-blanking output ( $\overline{RBO}$ ). The blanking out ( $\overline{BI}$ ) must be open or held at a HIGH level when output functions 0 through 15 are desired, and ripple-blanking input ( $\overline{RBI}$ ) must be open or at a HIGH level if blanking of a decimal 0 is not desired. X=input may be HIGH or LOW.
- (2) When a LOW level is applied to the blanking input (forced condition) all segment outputs go to a LOW level, regardless of the state of any other input condition.
- (3) When ripple-blanking input ( $\overline{RBI}$ ) and inputs A, B, C, and D are at LOW level, with the lamp test input at HIGH level, all segment outputs go to a HIGH level and the ripple-blanking output ( $\overline{RBO}$ ) goes to a LOW level (response condition).
- (4) When the blanking input/ripple-blanking output ( $\overline{BI}/\overline{RBO}$ ) is open or held at a HIGH level, and a LOW level is applied to lamp-test input, all segment outputs go to a LOW level.

## ADDERS

### 7483 4-BIT FULL ADDER

As the name implies, the adder is used to add numbers together. Adders have many applications such as in the Pong motion circuitry where an adder is used to provide correct motion codes. The codes produced by the image position circuit are too small for the motion circuit, so an adder adds the position code to a predetermined number to make it acceptable to the motion counter chains.

Adder outputs are indicated by the summation symbol ( $\Sigma$ ). The carry input and output are used when several adders are connected together to provide more bits. The carry output goes HI when the adder has filled up. When an adder is used individually, the carry input must be tied L0. When adders are connected together, the carry output of the first will advance the second.



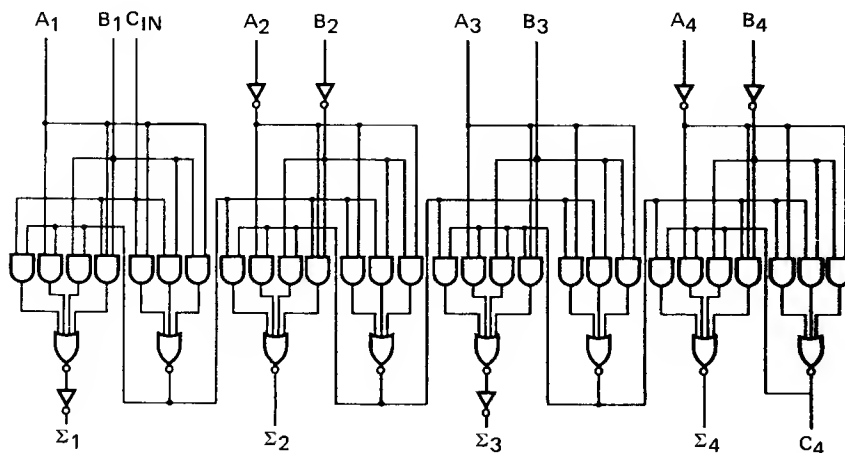
7483

#### PIN NAMES

A<sub>1</sub>, B<sub>1</sub>, A<sub>3</sub>, B<sub>3</sub>  
A<sub>2</sub>, B<sub>2</sub>, A<sub>4</sub>, B<sub>4</sub>  
C<sub>IN</sub>  
Σ<sub>1</sub>, Σ<sub>2</sub>, Σ<sub>3</sub>, Σ<sub>4</sub>  
C<sub>4</sub>

Data Inputs  
Data Inputs  
Carry Input  
Sum Outputs  
Carry Out Bit 4

INPUT				OUTPUT							
				WHEN C <sub>IN</sub> = 0				WHEN C <sub>IN</sub> = 1			
				WHEN C <sub>2</sub> = 0				WHEN C <sub>2</sub> = 1			
A <sub>1</sub>	B <sub>1</sub>	A <sub>2</sub>	B <sub>2</sub>	Σ <sub>1</sub>	Σ <sub>2</sub>	C <sub>2</sub>	Σ <sub>1</sub>	Σ <sub>2</sub>	C <sub>2</sub>	Σ <sub>3</sub>	C <sub>4</sub>
L	L	L	L	L	L	L	H	L	L	L	L
H	L	L	L	H	L	L	L	H	L	L	L
L	H	L	L	L	H	L	L	L	H	L	L
H	H	L	L	L	H	L	H	H	L	L	L
L	L	H	L	L	L	H	L	H	H	L	L
H	L	H	L	H	H	L	L	L	L	L	H
L	H	H	L	H	H	L	L	L	L	L	H
H	H	H	L	L	L	H	H	L	L	L	H
L	L	L	H	L	H	L	H	H	L	L	L
H	L	L	H	H	H	L	L	L	L	L	H
L	H	L	H	H	H	L	L	L	L	L	H
H	H	L	H	L	L	H	H	L	L	L	H
L	L	H	H	L	L	H	H	L	L	L	H
H	L	H	H	H	H	L	H	L	L	L	H
L	H	H	H	H	L	H	L	L	L	L	H
H	H	H	H	L	H	H	H	H	H	H	H



## LATCHES

The latch is an information storage device. Gran Trak uses these devices to store data retrieved from a read only memory (ROM) until it is needed for use. In this case, one latch is used to store the lap check point information and is also wired to another latch in such a way that the second one counts the laps as the race car passes the check points.

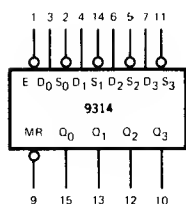
### 9314 QUAD LATCH

This latch can store up to four bits of information so it can be used for numbers as large as 1 1 1 1. It actually consists of four single-bit latches. A common enable is active L0. When the enable goes H1, the information at the inputs is stored and the latch is not affected if the information at the inputs changes. The information appears at the output when the enable returns L0. The master reset overrides all other input conditions and forces the outputs L0. It is also active L0.

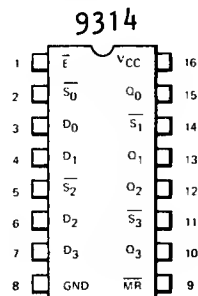
The latch can be connected in one of two modes: D Type or Set/Reset. In the D configuration, the  $\bar{S}$  inputs are held L0 and when the enable is active, the latch outputs reflect the D inputs. If the enable is L0 and if the latch is in the Set/Reset configuration, the latch is reset by a L0 input and can be set by a L0 on the  $\bar{S}$  input if the D input returns H1. If both  $\bar{S}$  and D are L0, the D input will dominate and the latch will be reset. When the enable goes H1, the latch remains in the last state prior to the L0 to H1 transistion.

#### PIN NAMES

$\bar{E}$   
D<sub>0</sub>, D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>  
 $\bar{S}_0$ ,  $\bar{S}_1$ ,  $\bar{S}_2$ ,  $\bar{S}_3$   
MR  
Q<sub>0</sub>, Q<sub>1</sub>, Q<sub>2</sub>, Q<sub>3</sub>



(Active LOW) Enable Input  
Data Inputs  
Set (Active LOW) Inputs  
Master Reset (Active LOW)  
Latch Outputs



MR	$\bar{E}$	D	$\bar{S}$	Q <sub>n</sub>	OPERATION
H	L	L	L	L	D MODE
H	L	H	L	H	
H	H	X	X	Q <sub>n-1</sub>	
H	L	L	L	L	R/S MODE
H	L	H	L	H	
H	L	L	H	L	
H	H	X	X	Q <sub>n-1</sub>	
L	X	X	X	L	RESET

X = Don't Care  
L = LOW Voltage Level  
H = HIGH Voltage Level

Q<sub>n-1</sub> = Previous Output State  
Q<sub>n</sub> = Present Output State

## SHIFT REGISTERS

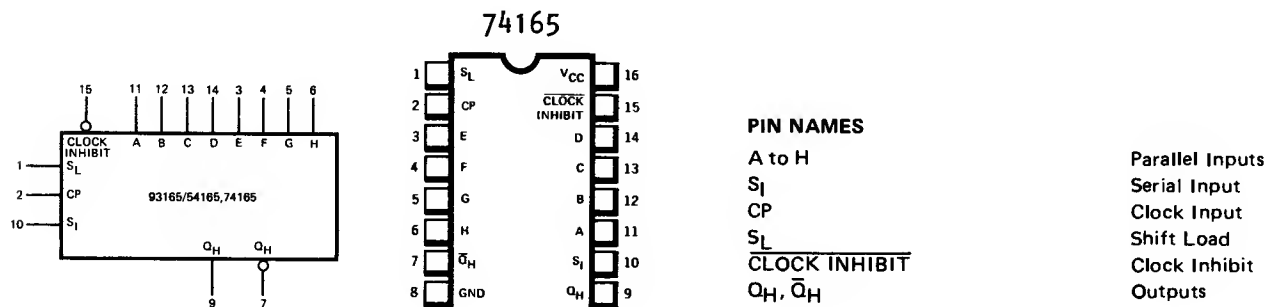
Shift registers convert parallel (simultaneously occurring) information to serial (sequentially occurring) information. In video games, the primary use for shift registers is the conversion of ROM information. The information from a ROM appears at all the outputs simultaneously, which is fine for processing by other parallel-loading devices, but not OK for displaying on the CRT. Since the electron beam scans the CRT a point at a time, the information to be displayed must be ordered one bit at a time. If four or eight bits were used simultaneously to intensify the beam, the resulting image would be just a white dot without meaning. If the bits are ordered, they can be displayed one after another to form a coherent image.

Essentially, a shift register is nothing more than a series of flip-flops. Each flip-flop stores one bit of information which is clocked out sequentially by a signal which occurs at the rate the information is needed.

### 74165 SERIAL TO PARALLEL CONVERTER

This is the most common device and it can process an eight bit word at a time. The data at the parallel inputs is loaded when the shift load input goes L0 and data is loaded independently of the state of the clock input. As long as the CLOCK INHIBIT pin is held H1, the information remains latched within the register. When this input drops L0, the clock pulse input reads out the information serially.

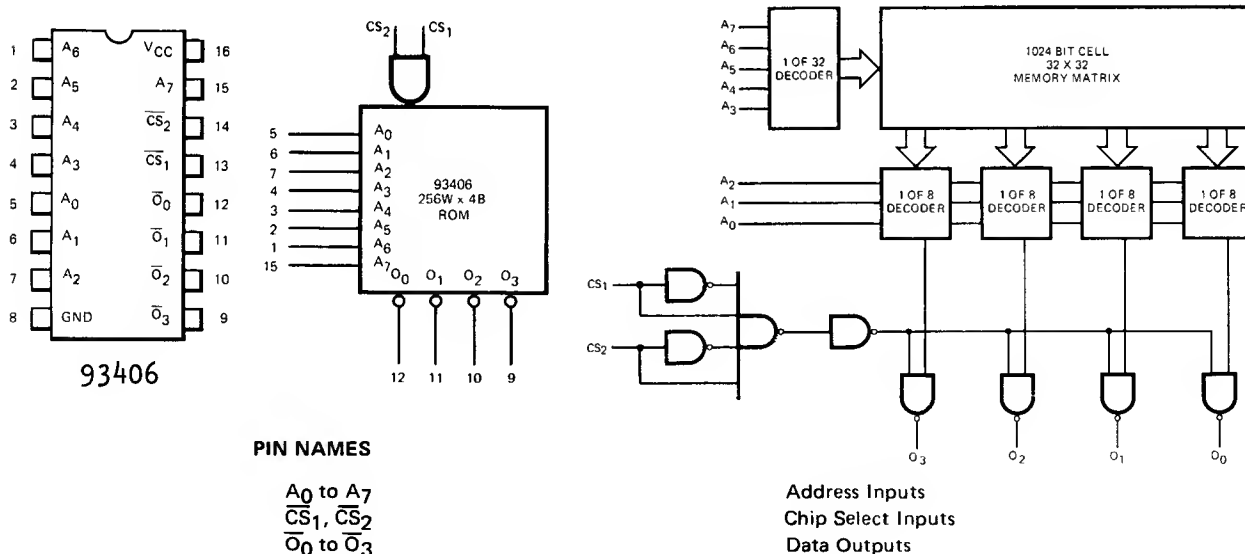
If a 16 bit word needs conversion, two shift registers are used. In this case, the serial output pin of the first is connected to the serial input pin of the second.



## READ ONLY MEMORIES (ROMS)

Integrated Read Only Memories (ROMs) are devices which permanently store binary information. Roms are especially useful in video games for storing complex images which would otherwise require a great deal of circuitry to generate. ROMs do have many other applications such as code conversion, controllers, etc. Each ROM is custom mask-programmed to store the particular information needed by the user. Recent advances in semiconductor technology have made fusible link and electrically reprogrammable ROMs a reality. The fusible link ROM is programmed by the user and the electrically reprogrammable ROM can be reprogrammed by first erasing the "old" information with ultraviolet light. ROMs less than 16K are generally bipolar TTL devices, useful for they are faster. Since 16K ROMs require so much space, CMOS technology must be used.

A typical ROM, such as the one illustrated below, may store 256 4-bit words (or 1024 bits in all). Each word is stored on a *line* which is addressed by a certain binary number. When a number is entered at the ROM inputs  $A_0$  to  $A_7$ , the ROM "looks up" the line with that number and all four bits of information stored on that line appear simultaneously at the four outputs. Generally, multiplexing schemes are used to address the ROM and often the address circuitry can be quite complex. ROMs are available in storage capacity up to 256 8-bit words (16,384 bits in all).

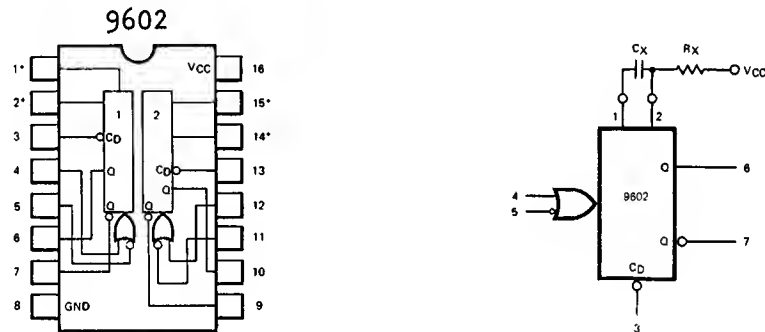


The only realistic way to check a ROM is by substituting another known-to-be-good one in its place. If this does not clear up the problem, the malfunction must then lie in the address or conversion circuitry. But before getting into this mess, be sure the basics such as V<sub>cc</sub> and GND are correct.

## 9602 DUAL RETRIGGERABLE MULTIVIBRATOR

Multivibrators, or *one-shots* as they are more commonly known, are useful for their ability to output a pulse, the duration and recurrence rate of which can be carefully controlled. The one-shot is useful in a wide variety of specialized circuits. Although not a completely digital device, the one-shot is compatible with all members of the TTL family. Output pulse width is controlled by an externally connected resistor-capacitor (RC) network.

The 9602 Dual Retriggerable, resettable multivibrator has two gate inputs (pins 4 and 5) per function (one active LO and one active HI) to select triggering on the leading or trailing edge. The reset input  $C_D$  must be HI to produce a pulse; a LO at  $C_D$  will terminate a pulse. If a repetitious output is desired, the input cycle time must be shorter than the output pulse width.



### PIN NAMES

$\bar{B}$	Trigger (Active LOW) Input
A	Trigger (Active HIGH) Input
$\bar{C}_D$	Clear (Active LOW) Input
Q	Output (Active HIGH)
$\bar{Q}$	Output (Active LOW)

## LINEAR DEVICES

Integrated analog or *linear* devices are often used alongside digital devices to provide special functions. Digital devices controlled by binary logic levels and output information in the same form; the output of linear devices changes proportionally to input parameters. Many linear devices are manufactured to be compatible with TTL products. Linear components like these are packaged in dual in-line packages and are generally found in the digital section of the PCB. Other linear devices have applications in the discrete circuitry (i.e. the power supply) and are found in the discrete section of the PCB.

## 555 TIMER

The 555 timer is a device similar to the one-shot in that an externally connected RC network controls output pulse width. However it is different in that the 555 does not have a gate input; it is controlled by an analog signal such as a pot which is used to vary the RC time constant. The main applications of the timer are in game timers and paddle circuits.

The timer may be connected in one of two modes. In the *monostable* mode, it outputs a single pulse when enabled. In the *astable* configuration, the timer may be used to generate a series of precisely timed pulses, so accurate that the signal can even be used for the system clock.

When used as a game timer, the 555 is connected in the astable mode and it outputs a pulse train which is used to clock a counter. The counter counts the number of pulses and when it has reached a pre-determined number, it generates an end game signal. An external trim pot is used to vary the timer output pulse width and recurrence rate and therefore controls the game time. A good analysis of this application appears in the Gran Trak manual.

When used in a paddle circuit, the 555 is connected in the monostable configuration. Typically, the timer is connected similarly to Figure 31. The trigger input signal 256V is used to limit the lower end of paddle travel, since 256V goes HI at the bottom of the CRT. The timer's threshold level is controlled through pin 6 and an adjustable trim pot (R1) is placed in this line to allow correct positioning of the top limit of paddle travel. The player's control consists of an externally mounted pot (R2) connected to the VC0 input of the timer. The potential at the VC0 determines the time it takes to charge capacitor C1. Varying charge time causes the output pulse to be generated sooner or later with respect to the raster timing. The output pulse is used to enable a four-bit counter which counts out the actual paddle length of 16 lines. Therefore, the later the timer output pulse arrives with respect to when the electron beam began its sweep, the lower down the screen the image will be generated.

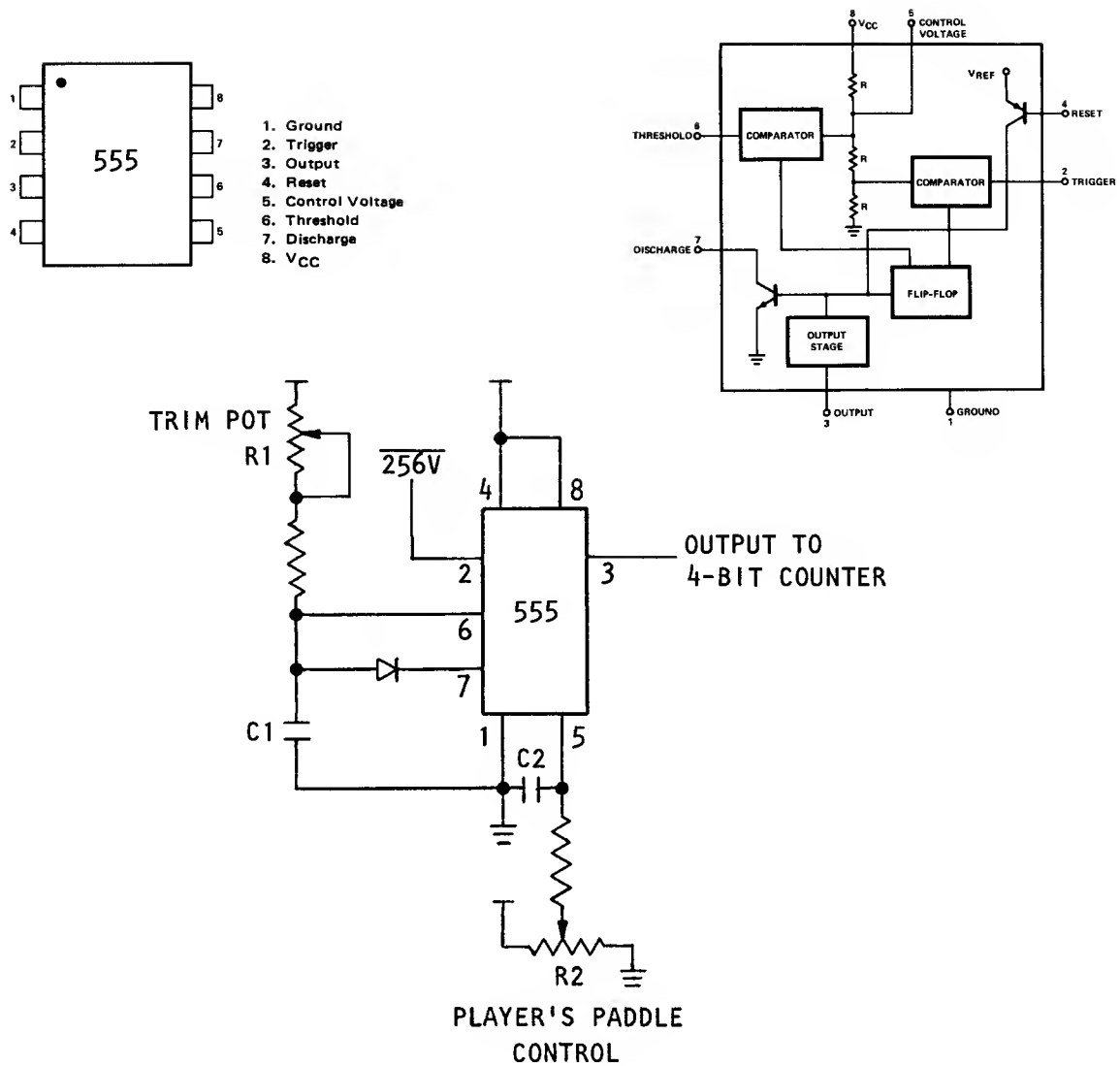
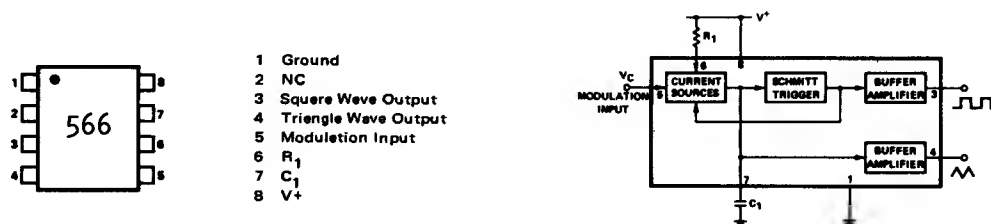


FIGURE 31  
A TYPICAL PADDLE CIRCUIT

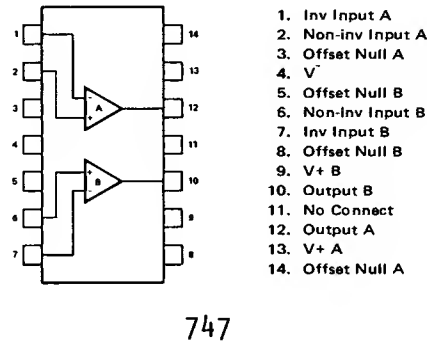
## 566 FUNCTION GENERATOR

The 566 Function Generator is a voltage controlled oscillator (VCO) with both square and triangle wave outputs. The oscillation frequency is controlled by an externally connected RC network and the voltage applied to the control terminal. See pages 2-8 and 2-9 of the Gran Trak manual for application notes.



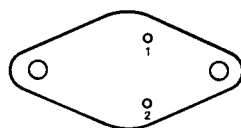
## 747 OPERATIONAL AMPLIFIER

The number of different applications of this device are almost endless. It may be found in power supplies and many types of specialized circuits. Essentially, the amplifier is used to detect a difference between the (+) and (-) inputs and the difference used as a control for another device. The 747 is basically a dual 741.



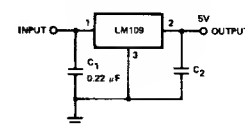
## LM 309 VOLTAGE REGULATOR

The LM 309 is an integrated voltage regulator designed specifically for use with TTL components. It has greatly simplified power supply design for it replaces several transistors, an opamp and a handful of resistors and capacitors. Since the case is grounded, it requires only two connections: input (pulsating +5 volts DC) and output (regulated +5 volts DC). If provided with adequate heat-sinking, the LM 309 is good for more than an amp of regulated output. That is why there is such a large heatsink around it. Since 1 amp is often not enough to adequately power a computer, a large wire wound resistor is often connected across the input and output of the LM 309 to provide greater current capability. If this still is not enough, an LM 323 is used which is good to about 3 amps.



LM 309

### FIXED 5V REGULATOR



# CHAPTER V

## GENERAL TROUBLESHOOTING PROCEDURES

Because of the fact that this manual is written for video games in general, it is difficult to offer specific instructions for troubleshooting particular games. To detail the troubleshooting procedures for each game would involve hundreds of pages of more or less repetitive instructions which would differ only in the specific details of the particular game. However, it is within our scope to offer generalized troubleshooting procedures which apply to most, if not all, Atari video games. While we will not be able to instruct you in how to deal with specific problems as related to particular games, we will be able to suggest ways to approach common types of malfunctions.

The most common problems occur in harness components such as the coin acceptor, the player's controls, the interconnecting wiring, etc. These areas will be covered in moderate detail. The TV monitor and the PCB computer do cause their share of problems, but not to the same degree as the harness and its component parts. TV monitor troubleshooting will not be covered in detail because there is already so much literature available on this subject. However, we are including the Motorola schematic for those brave souls who enjoy broken monitors and who have the necessary test equipment and we will instruct you in how to differentiate between monitor and computer malfunctions as this is an area which has caused much confusion in the past.

As you already know, the PCB computer is a complex device with a number of different circuits. Some circuits remain basically the same from game to game, but overall there are a great many differences between game types. PCB troubleshooting procedures therefore can be lengthy and will differ greatly from game to game. This being true, it is difficult to offer any valuable troubleshooting information without referencing it to specific games. Since this manual is limited to general video game information, we can only offer generalized approaches to PCB malfunctions. The specific details concerning procedures for troubleshooting particular games can be found in the computer service manuals published for many Atari games.

## GENERAL TROUBLESHOOTING SUGGESTIONS

The first step in any troubleshooting procedure is correct identification of the observable symptoms of the malfunction. This includes not only the circuits or features which are malfunctioning, but also those which are still operational. A carefully trained eye will pick up other clues as well. For instance, a game in which the computer functions fail completely immediately after being collected is suspected of having a quarter shorting traces on the PCB. Often, an experienced troubleshooter will be able to spot the cause of the problem before he even opens the cabinet.

After all the clues are carefully considered, the possibly malfunctioning areas can be narrowed down to one or two good suspects and those areas examined in a process of elimination until the cause of the malfunction is discovered.

## HARNESS COMPONENT TROUBLESHOOTING

Typical problems falling in this category are coin and credit problems, power problems and failure of individual features.

### NO GAME CREDIT

For example, your prospective player inserts his quarter and is not awarded a game. The first item to check is if the quarter is returned. If the quarter *is returned*, the malfunction most certainly lies in the coin acceptor itself. First, use a set of test coins (both old and new) to ascertain that the player's coin is not undersize or underweight. If your test coins are also returned, coin acceptor servicing is indicated. Generally, the cause of this particular problem is a maladjusted magnet gate. Normally, this will mean closing the magnet gate a bit by turning the adjusting screw *out* a bit (see page 26 for more details concerning this adjustment).

If the quarter is not returned and there is no game credit, the cause of the malfunction may be in one of several areas. First try operating the coin return button and if the coin is returned, the problem is most likely in the magnet gate. Enlarge the gap according to the coin acceptor service procedures. If this does not cure the problem, remove the coin acceptor, clean it and perform the major adjustment procedure.

If the trapped coin is not returned when the wiper operating lever is actuated, you may have an acceptor which is jammed by a slug, gummed up with beer, a jammed coin chute or mechanical failure of the acceptor mechanism. In this case, first check for the slug which will generally be trapped against the magnet. If so, simply remove the slug and test the acceptor. If the chute is blocked, remove the acceptor and clean out the jammed up coins. If there is actual failure of the acceptor, remove the unit and repair as indicated in the coin acceptor service procedures.

If the coin is making its way through the acceptor (i.e. falling into the coin box), yet there is still no game credit, you either have a mechanical failure of the coin switch or electrical failure of the coin and credit circuit. The first place to begin is by checking the coin switch. Most of these switches are the make-break variety of micro switch and it is checked by testing for continuity between the NO and NC terminals and the C terminal. When unactuated, the NC and C terminals should be continuous and the NO terminal open. When operated, the NO and C terminals should close and the NC should be open. If the coin switch checks out, examine the connections to the terminals making sure there is good contact. If necessary, use the continuity tester and check from the terminal lug on the switch to the associated PCB trace. This will tell you if there is a continuous line all the way to the credit circuit.

If the coin switch wires do check out, the problem is in the computer and most likely in the coin and credit circuitry. Before attempting to troubleshoot this circuit, read pages 2-2 and 2-3 of the Gran Trak 10 manual which describes in detail the operation of and troubleshooting procedures for credit circuitry.

If you do get game credit when a coin is deposited, but the game will not start when the start switch is pressed, you may have a problem in the start switch, the interconnecting wiring or in the computer. First check the switch. Most games now have a Licon LED switch which illuminates when there is game credit. If the LED does not light, you probably do not have credit, although LED circuit failure is a possibility. In any case, check the switch as you would any other, but keep in mind that two of the switch terminals are used for the LED.

If the switch is OK, proceed to check the wiring. Again, make sure you go from the terminal lug on the switch to the PCB trace. This way, you will check the terminal contact as well as PCB edge connector contact. If the wiring is continuous, proceed to check the PCB credit circuit. If not, check each section of the wiring, until the discontinuity is located.

If the wiring is OK, the problem must lie in the computer. Refer to the Credit and Start section of the Gran Trak manual and troubleshoot your circuit similarly.

## **TRANSFORMER AND LINE VOLTAGE PROBLEMS**

Your machine must have the correct line voltage to operate. If the line voltage drops too low, a circuit in the computer will disable game credit. The point at which the computer will fail to work will vary to some degree from game to game, but no machine will work on line voltage which drops below 105 VAC.

Low line voltage may have many causes. Line voltage normally fluctuates a certain amount during the day as the total usage varies. Peak usage times occur mainly at dawn or dusk, so if your machine's malfunction seems to be related to the time of day, this may be a factor. A large load connected to the same line as the game (i.e. a large air conditioner or other device with an exceptionally large motor) may drop the line voltage significantly when starting up. This can produce a temporary drop in line voltage resulting in an intermittent credit problem. Additionally, poor connections in the location wiring, the plug or the line cord may also cause a significant drop in power. Cold solder joints in the machine's harness, especially in areas like the transformer connections, the interlock switch, the fuse block, etc. may also produce the same results, although probably on a more permanent basis.

Sometimes location owners (especially bars) replace light switches with dimmer rheostats and sometimes the game is on the same line. Obviously, the voltage available to the game is going to drop dramatically when the dimmer is turned.

In any case, the way to check for correct line voltage is with your VOM. Set the VOM to 250 VAC and stick the probes in the wall receptacle. If OK here,

check the transformer primary connections. If you do not get 117 VAC, examine the solder joints on the transformer, fuse block and interlock switch. If you do get 117 VAC, the problem must be either in the transformer, the harness connections or in the PCB power supply.

If you suspect the transformer, check its secondaries with the VOM set to 50 VAC and correlate the readings with the legend on the side of the transformer. The transformer must also be correctly grounded, so check the ground potential as well, especially if there is a hum bar rolling up or down the TV screen.

## **NO POWER, NO PICTURE**

If the TV screen is completely dark, first look in back of the monitor to see if the CRT filament is glowing. If it is, try adjusting the brightness control. If no luck here, put your ear near the TV and listen for the high pitched B+ hum produced by the flyback transformer. If you get hum, but no picture and you have tried adjusting brightness, major TV servicing is indicated.

If the monitor seems completely dead, check to see if the rest of the game is energized. If not, go directly to the wall receptacle and check there. If OK there, check the game fuse, interlock switch and interconnecting wire lengths.

Sometimes it is difficult to tell if a Slo-Blow fuse has blown. If in doubt, check it using any of the VOM "R" scales.

## **HARNESS PROBLEMS**

Other harness problems include blowing fuses and malfunctioning controls. The repeating blown fuse problem can sometimes be quite exasperating to solve for short circuits have the tendency to occur in areas which are almost impossible to find. First, try inserting a new fuse as old fuses age and blow without cause. If the new one also blows, you definitely have a short. The best way to approach this problem is by disconnecting devices which may be causing it, such as the TV, the transformer and the PCB. Disconnect the devices by pulling off their connectors, but make sure not to allow them to touch. If necessary, insulate them with small pieces of electrical tape. Then, connect your VOM across the terminals of the fuse block (all electrical power shut off) and

set it to one of the resistance scales. This will save blowing a fuse each time you want to check the circuit. If the VOM reveals that disconnecting the devices removed the short, reconnect the devices one by one and find which one is at fault. If the VOM reads a short even after the devices are disconnected, the fault must lie in the harness itself and only patient exploration will reveal its location. First, carefully examine all the wiring looking for terminals which may be touching, metal objects such as coins shorting connections, burned insulation, etc. If necessary, use the VOM to check each suspected wire.

## **MALFUNCTIONING CONTROLS**

The most common problem here is the bad potentiometer. Typically, a bad pot will cause the paddle image to jump as it reaches a certain point (see page 19). The only cure for this one is to install a new pot.

If a feature which is operated by a switch (e.g. joysticks, foot pedals, control panel buttons) does not operate at all, check the switch with a VOM or continuity tester to verify its operation. If the switch does not check out, replace it. If the switch is OK, the input to the switch from the PCB is suspected. In this case, get out the harness and logic schematics and check to see what kind of input it is. In many cases, the input will be +5 VDC. In this case, use the VOM to check its presence. Normally, the switch is used to pull a +5 VDC line LO to GND or to pull a LO line HI. If the PCB output is missing, check the wire length from the PCB. If you find the signal at the PCB trace, the wire length or connection is at fault. If not, begin exploring the PCB using the logic schematics and game manual.

## **TV MONITOR PROCEDURES**

The three main monitor problems are (1) no raster and no picture, (2) raster and no picture and (3) a distorted picture. The aim of this section is to instruct you how to tell if the monitor is definitely malfunctioning, but we are not going to delve any deeper into monitor troubleshooting. Once you have determined that your monitor is behaving incorrectly you have two choices: you may remove it and take it to a local TV repair shop have it repaired there and save yourself the headache or you can take two aspirin tablets and try to fix

it yourself. Generally speaking, TV repair is best handled by those who know what they are doing and have the necessary TV repair instruments (a scope, a VTVM and some signal generating equipment). If you do know something about TV repair and have the necessary equipment, turn to page 88 and go to it. Motorola repair manuals are available from your Atari Field Service Representative free of charge. This manual is quite complete and contains a nicely written theory of operation section as well.

## **NO RASTER, NO PICTURE**

First, check to see if the filament in the rear of the CRT is glowing. If not, proceed to check the line voltage at the monitor. Be aware that the monitor is fused separately so check its own fuse. If it is difficult to see if the fuse is good, turn off all power, remove the fuse and test it with the VOM. If the fuse is good and the filament will not glow, troubleshoot the power supply of the monitor and the CRT or take the TV elsewhere to be repaired.

## **RASTER, BUT NO PICTURE**

If you have a correct raster (that pattern of lines generated by an unmodulated electron beam) but no video display, you may have any one of the following problems: (1) the PCB may not be outputting the video information, (2) the PCB is functioning correctly, but the monitor is not receiving the signal or (3) the monitor is receiving the information but is not processing it correctly.

There are many techniques for differentiating between the good and malfunctioning components. The *substitution* technique is widely used. In this case, plug the PCB into your test fixture or another identical game and if the game video display comes up on the screen, the other TV must be malfunctioning. Or, if you are at a location with two video games and no test equipment, run some jumpers from the PCB of the suspected game to the monitor of the other or visa versa.

The TV Sync probe will be of no value in this case since it can only verify the presence of sync signals. It is not sensitive to video signals and will give no indication of their presence.

Another quick and dirty monitor test is as follows: disconnect the PCB edge connector and turn the monitor brightness all the way up. Touch your finger to the video input line somewhere and, if the monitor is OK, your body capacitance should cause faint vertical columns to appear on the CRT.

If the TV monitor appears to be functioning correctly, the PCB becomes suspect. First check the video output (COMP VIDEO) which should be HI, LO and PULSING. If OK here, check each video input into the video summing network. If you do not get HI, LO and PULSING at all of these points, there is definitely PCB failure. Begin troubleshooting by verifying the +5 VDC line. If OK here, go to the sync circuits and check them. If they are also OK, get out your copy of the game computer service manual and proceed as indicated there.

## **DISTORTED PICTURE**

Typical symptoms include a picture which is rolling up or down the CRT or is *tearing* (broken up) horizontally. In this case you may have incorrect PCB sync signals, a malfunctioning monitor or a monitor which is in need of adjustment. If the picture is rolling, it is out of sync vertically, so try adjusting the vertical hold first. If it is broken up into a series of diagonal lines, it is out of sync horizontally, so try adjusting the horizontal hold control.

If this does not help, then check for sync with the TV Sync probe if you have one. If not, use the logic probe and if sync appears to be OK, the monitor is most likely in need of servicing. To definitively prove which component is at fault, dust off your scope and check PCB sync or use the substitution technique to verify PCB operation.

## **HUM BARS**

*Hum bars* are annoying black horizontal bars which roll up or down the CRT. They may have many different causes, but the most likely is a power supply dropping out of regulation. If you have a scope, check to see if there is a ripple on the +5 VDC line. If so, the power supply is definitely dropping out. This may be caused by overloading of the power supply, low line voltage or poor contact at the transformer to GND connection. If no luck here, begin troubleshooting the power supply itself.



## TESTING THE PCB

Printed circuit board troubleshooting is by far the most complicated fault-finding task in video game repair. It requires an extensive complement of test equipment and a good working knowledge of digital device and video game operation. But the most critical factor is experience. At first, computer malfunctions seem almost impossible to locate because the entire computer seems so vast and so complex. But after a few weeks of serious effort and study, it boils down to merely a set of circuits whose functions and relationships are understood and a number of common problems which seem to constantly reappear. The only advice we can offer in this regard is to stay with it through the difficult period until things get better.

The computer service manuals can be very helpful in aiding your understanding of computer architecture. These manuals contain all the electrical documentation for the game, descriptions and analyses of each circuit and a complete set of test points. Reading the circuit analyses will acquaint you with the various circuits and their functions and this is the most important area to concentrate on at first. Many circuits such as the power supply, clock, sync and the credit circuitry remain the same in each game and you should start with these. Once you have learned these basic circuits, then explore the areas which differ from game to game. No doubt you will also notice many similarities here as well. For example, nearly all paddle circuits are identical and 7-segment score displays all share a common pattern.

The Gran Trak manual included at the end of this handbook is exemplary of these computer service manuals. Gran Trak is an excellent game to get familiar with because not only does it contain all the common circuits, but it also contains most of the other devices which may be employed in various other games. These devices include the ROM, the analog hybrids, the steering circuitry photo diodes, operational amplifiers, etc. If you are new to video game repair, it would be wise to locate a Gran Trak computer and follow through with the manual, reading the circuit descriptions and testing all the points called out in the text to familiarize yourself with correctly operating circuits and test procedures.

## GENERAL PCB TROUBLESHOOTING APPROACHES

If you have generalized failure of the PCB, begin by checking the power supply. The power supply must output a regulated +5 VDC and possibly other voltages as well depending on the individual game. But first, check for +5 VDC using your VOM and if there is incorrect voltage here begin examining at the transformer secondary inputs to the PCB. If OK here, check the diodes which rectify this current and if these outputs are good (about 8.5 VDC with a VOM), the problem is most likely in the LM 309. Check the regulator input and if it is OK, replace the LM 309 as necessary. Keep in mind that it is normal for the LM 309 to shut down if thermal dissipation becomes too great. It will restart when it cools.

If the power supply is OK, however generalized failure persists, check the oscillator output with the logic probe (HI, LO and PULSING) or your scope (14 MHz sine wave before shaping and 7 MHz square wave after). If the clock is OK, check both sync circuits by examining the counter outputs with a logic probe, video probe or oscilloscope. The logic probe should read HI, LO and PULSING at all outputs and the video probe will reveal a series of bars (horizontal for vertical sync and vertical for horizontal sync) which double in size at each successive division. Be sure to check the reset, blanking and sync pulses. It is best to do this with a scope which will indicate the precise timing relationships. If you do not have a scope, check for general presence with the logic probe. If you have a TV Sync probe, you can verify correct sync immediately without bothering with any intermediate steps.

If you have credit and/or start problems, start by examining the credit circuitry with the aid of the game computer manual. Keep in mind that ATTRACT must go LO to enable the game play mode functions. If not, check the attract flip-flops, the credit flip-flops and the electronic latch by using the information in the computer manual. If the game ends prematurely, check for correct antenna adjustment and latch operation.

If an image is missing or distorted, go directly to the circuit which produces that image. If a ROM is involved, check it by substitution. If you cannot obtain another ROM, you may have to check both the address and conversion cir-

cuitry. Incorrect score displays are often caused by a malfunctioning decoder or the multiplexers which create the 7-segment display. Incorrect playfield displays may have many causes depending on the particular game.

If the game timer does not work, check the 555 and the RC network. Games which end at a certain score are controlled by a score circuit output which shuts off credit in the credit circuit. In this case, check the score circuit output and the credit flip-flops. Incorrect score counting is most likely rooted in the score storage circuit.

Sound circuits may or may not have their own amplifiers. If the sound is completely missing, first check the volume control. Then investigate the speaker and amplifier. A quick and dirty speaker test involves jumping alternating current directly to the speaker *momentarily*. If the speaker is good, you will hear a loud buzz. If some of the sounds are missing or distorted, check the sound circuit itself.

If the moving images move erratically, do not move at all or if there are a whole bunch of them all over the screen, check the motion circuits carefully with the aid of the computer service manual. Motion circuits are checked in essentially the same way as sync circuits.

# GRAN TRAK 10 & TRAK 10

## COMPUTER SERVICE MANUAL

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# 1. GENERAL MAINTENANCE INFORMATION

## 1-1. INTRODUCTION

1-2. Gran Trak 10 is a new type of video game, and the operation of the new circuitry must be learned before your troubleshooting attempts will be successful. However, after the basic differences are understood, it should prove no more difficult than any other Atari printed circuit board (PCB) computer. The main differences between GT-10 and previous Atari games are the steering circuitry, the hybrid chips, the ROM (read only memory) and the power supply.

1-3. The steering circuitry is a novel bit of engineering which employs phototransistors and infrared light emitting diodes to generate pulses indicating the direction of steering wheel rotation. Fortunately, it is quite a simple circuit and easy to troubleshoot.

1-4. The hybrids are three custom chips which have been specially manufactured for this game. Troubleshooting these chips involves only verifying the correct input/output conditions and replacing the chip if the output conditions are not correct.

1-5. The ROM is another chip which has been specially programmed for GT-10 and it is used to generate the information for the display of the car, the score and game timer and the race track. Troubleshooting the ROM is probably one of the easiest tasks because it involves only unplugging the suspected chip and replacing it with a known-to-be-good ROM.

1-6. The power supply is more complicated because additional voltages are needed to operate the ROM, the hybrids and the on-board audio amplifier. Even though there are a few more voltages to check, the basic power supply troubleshooting methods remain unchanged.

## 1-7. TEST EQUIPMENT

1-8. Because of this new circuitry, more test equipment is required to check the PCB. An oscilloscope is an absolute necessity and a logic comparator would be a wise investment.

1-9. Some of the following instruments are absolutely essential to fully test the GT-10 PCB; others are desirable because they make the test procedures easier, but are not essential. Many of these items are available from the Atari Customer Service Department, and these items are indicated by an asterisk (\*). A few others are available only

from electronics supply houses or rental agencies; however, if you have difficulty in obtaining any needed instrument, contact Atari Customer Service for assistance.

**1-10. Required Equipment:** Atari recommends the following as a minimum set of test equipment:

a. **Logic Probe\*:** The logic probe is an instrument designed for checking the outputs of integrated circuits. Atari recommends the Kurz-Kasch Logic Probe, model No. LP-520. The logic probe will indicate if a signal is a logic high, low or changing from one state to the other. Consult the operating instructions included with the unit for further details on its operation.

b. **Video Probe\*:** The video probe is a simple, but useful testing device. It consists of two IC test clips (or one clip and a test prod), a length of wire and a 4.7K, 1/4W carbon resistor. Video probes may be obtained free of charge from the Atari Customer Service Department, or, if necessary, they can be assembled from standard parts available at any electronics supply house. To use the video probe, attach one clip to the negative side of the video coupling capacitor (C44) and clip or touch the other end to the desired signal test points as indicated in the following pages. The VP will display the signal directly on the CRT.

c. **The Oscilloscope:** The oscilloscope is used for viewing various waveforms. The application requires at least a 50 MHz scope and a dual trace unit to facilitate comparison between waveforms is desirable. Atari's specific recommendation is the Tektronix model No. 465, 100 MHz dual trace oscilloscope.

d. **Atari Universal Test Fixture:** The Atari Universal Test Fixture can be used to test the computer boards for Pong, Pong Doubles, Super Pong, Rebound, Space Race, Gotcha, and Quadrapong. This test fixture is equipped with a 12 inch TV monitor, two 5 volt BNC connectors for use where a regulated 5 volt source is required, and all the controls necessary to operate the computer boards. Connector cables must be ordered separately for each different type of PCB to be tested. The test fixture and cables are only available through the Atari Customer Service Department.

**1-11. Optional Equipment:** The following pieces of test equipment are not essential but will make your troubleshooting easier.

**a. The Logic Comparator\*:** This compact troubleshooting instrument will prove invaluable in verifying correct IC operation. The unit simply clips onto in-circuit ICs and instantly displays any logic state difference between the in-circuit test IC and the reference IC in the comparator. Logic differences are identified to the specific pin by a lighted LED. If this instrument is purchased from the Atari Customer Service Department, it will be shipped with 20 pre-programmed reference boards. If the instrument is purchased elsewhere, you will have to program the boards yourself. Atari recommends either the Hewlett Packard 10529A comparator or the Fluke comparator.

**b. The Logic Pulser\*:** The logic pulser is used to stimulate in-circuit ICs so they are driven to their opposite states and we recommend the Hewlett Packard 10526T pulser.

## 1-12. TROUBLESHOOTING SUGGESTIONS

**1-13.** The first step in the troubleshooting process is to correctly identify the observable symptoms of the malfunction and then to narrow down the possibly malfunctioning areas as much as you can. This should reduce the situation to one or two functional blocks which might be at fault. Then start examining these functional blocks with your test instruments and compare the results with the operational analysis and test point information under the heading of that functional block. Keep in mind, however, that the first observable symptoms of a malfunction are not necessarily due to the functional block which produced those symptoms. A failure in one part of the PCB may affect much, if not all, of the PCB.

**1-14.** Some malfunctions may produce symptoms which are not clearly attributable to one component. Sync problems can be especially nasty in this regard because you can spend quite some time verifying the presence of correct sync signals on the board only to discover it is the monitor which is distorting sync.

**1-15.** For these problems, use substitution as a troubleshooting technique. For instance, to clearly identify which component is at fault in a sync problem, try substituting a known-to-be-good TV monitor. If you have built a test fixture, plug the suspected board into the fixture and if the sync problem disappears, the other TV must have been the

cause. Conversely, had the problem not disappeared, the substitution test would have revealed a malfunctioning board and you would begin the troubleshooting process at the sync section.

**1-16.** The same technique can be used to test the Read Only Memory (ROM) which is inserted in a plug-in type receptacle to facilitate the substitution test. If you have a problem with the car image, the race track display or the score or timer displays, try inserting another and known-to-be-good ROM and if this clears up the malfunction, leave it there. However, we must note that the ROM failure rate has been extremely low so it is more likely that a display problem is located in either the ROM address circuitry or the display circuits.

**1-17.** There are a few other problems which need mentioning because, while they may at first appear to be board related, closer examination will reveal they are location related. If the ac line voltage fluctuates enough, the electronic latch will turn off game credit. One cause of this may be a large load connected to the same line as the machine. For example, a large air conditioner while starting up may drop the line voltage enough to break the electronic latch. Another cause may be that the line voltage drops at certain peak times of the day (e.g., dusk). Local ac power is suspect in any malfunction which occurs on an intermittent basis.

**1-18.** Another game credit problem which may be either constant or intermittent in nature is a maladjusted antenna wire. The antenna wire is connected to the electronic latch and, if the wire is too long, game credit may be accidentally turned off, especially if the machine is in a carpeted location.

## 1-19. PCB ADJUSTMENTS

**1-20.** Most of the PCB adjustments are quite simple and only involve changing a slide switch to the desired position or adjusting a small blue trim pot "by ear". A few others, however, are more complex and require an oscilloscope or, preferably, a frequency counter. This section contains only the adjustment procedures; consult the text for a fuller understanding of how these adjustments affect their associated circuits. See Figure 2-32 for the location of the PCB adjustments.

**a. Test Switch:** While you are testing the PCB, you may wish to set this switch to the TEST position which will freeze the game timer and disable the crash mode. Always return the switch to the PLAY position before placing the PCB back in operation.

**b. 1P-2P Switch:** If this switch is set to the 1P position, the player will receive one game per each coin he deposits; if set to the 2P position, he will receive two games.

**c. Volume Adjustment:** This pot controls the gain of the audio amplifier. Adjust the volume to the preference of the location, and keep in mind that the machine will sound louder with the door off.

**d. Play Time Adjustment:** This pot controls both the total game length and the crash time period. The play time counter (to the right of the lap score in the pit area) always begins counting down from 78 by 2's. Adjusting the play time pot causes the game counter to count down slower or faster. Adjusting for a longer game will also increase the length of the crash time, and affect score interpretation per the "rating card" posted on front of the CRT.

**e. Speed Adjustment:** This adjustment controls the maximum velocity of the car. You must have either a logic probe or an oscilloscope to perform this adjustment. Attach the probe to B2-9 and adjust the pot until the signal ( $\overline{1\text{ STOP}}$ ) goes completely high when the car is traveling at maximum speed in third gear.

**f. "A" Adjustment:** You must have an oscilloscope or a frequency counter to adjust the following three engine sounds (A, B & C). Clip the test instrument to C8-3 (the square wave output pin)

and adjust the A pot for a 13 ms square wave or a frequency counter reading of 73 Hz.

**g. "B" Adjustment:** Clip test instrument to D8-3 and adjust the pot for a 3.07 ms square wave or a frequency of 325 Hz.


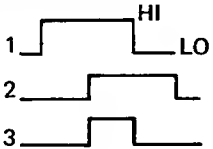

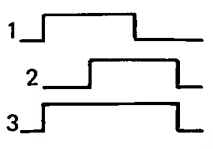
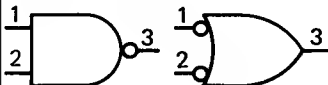
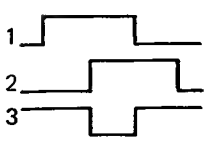
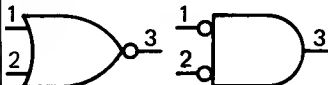
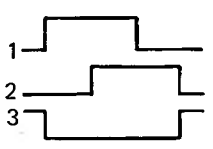

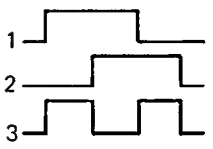
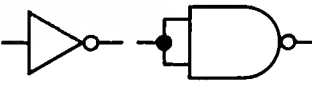
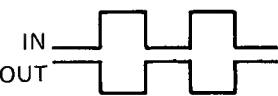
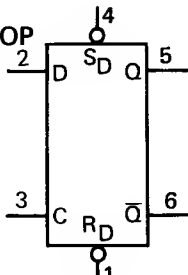
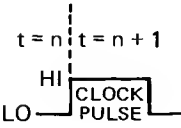
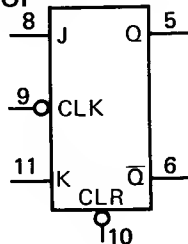
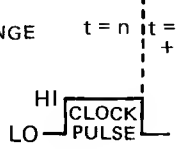
**h. "C" Adjustment:** Clip test instrument to E8-3 and adjust the pot for a 7.42 ms square wave or a frequency of 412 Hz.

**i. Screech Adjustment:** This pot adjusts both the screech and crash sounds simultaneously. Adjust the pot by ear for the best sound output.

## 1-21. LOGIC SYMBOLLOGY

1-22. Table 1-1 describes the operation of the most common logic circuits found on the computer board. Those not covered in the table are explained at their first appearance in the computer board circuit description in Section 2. Logic circuits are identified in the text and on the schematic by their actual grid location on the PCB and their output pin number (e.g., gate A6-3 would be the gate with output pin 3 in the logic package at location A6 on the PCB). The logic levels on the PCB are 0 to +0.4 volts for LO and +2.6 to +5 volts for HI. Signal names overscored (e.g.,  $\overline{\text{START}}$  and pronounced "start not") go LO to initiate events and those not overscored go HI when active. Overscored signals are always at the logic level opposite to that of their non-overscored counterparts (i.e.,  $\overline{\text{START}}$  is always at a logic level opposite to START).

Table 1-1. Logic Symboly

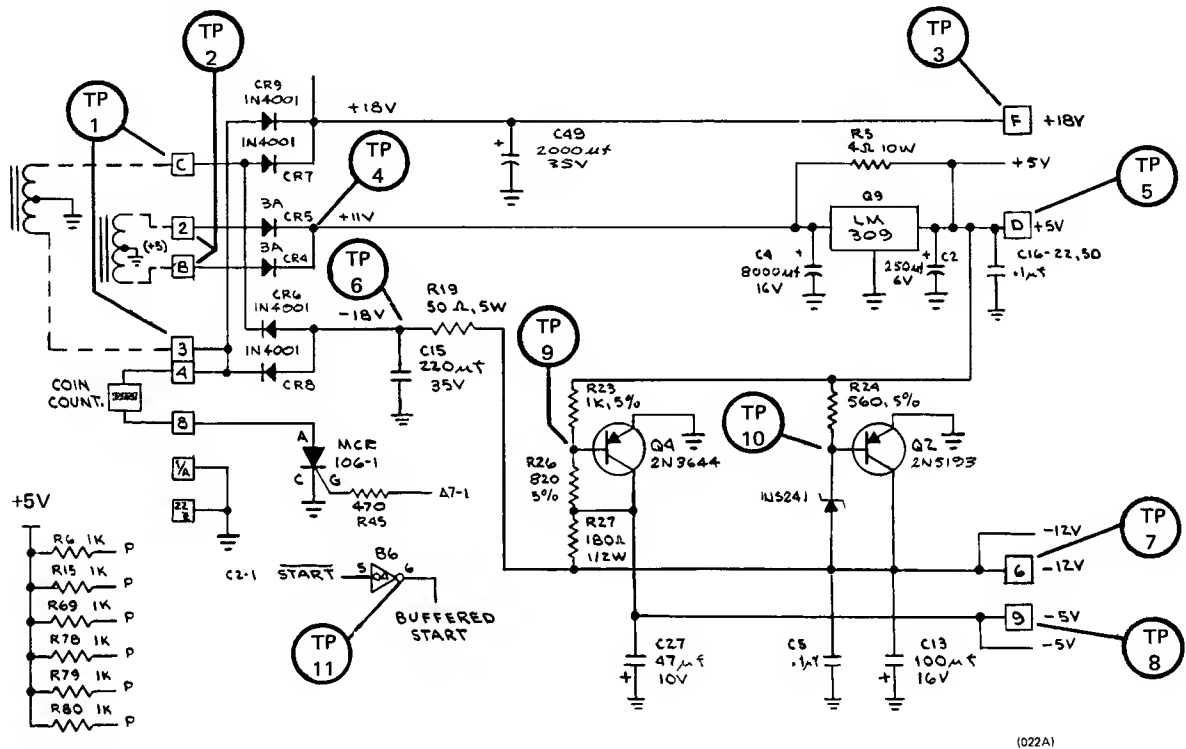
SYMBOL	TRUTH TABLE/TIMING	OPERATION																					
<b>AND GATE</b> 	<table border="1"> <thead> <tr> <th>1</th><th>2</th><th>3</th></tr> </thead> <tbody> <tr><td>LO</td><td>LO</td><td>LO</td></tr> <tr><td>LO</td><td>HI</td><td>LO</td></tr> <tr><td>HI</td><td>LO</td><td>LO</td></tr> <tr><td>HI</td><td>HI</td><td>HI</td></tr> </tbody> </table> 	1	2	3	LO	LO	LO	LO	HI	LO	HI	LO	LO	HI	HI	HI	Output is HI only when <u>all</u> inputs are HI, otherwise output is LO. Rule applies for any number of inputs.						
1	2	3																					
LO	LO	LO																					
LO	HI	LO																					
HI	LO	LO																					
HI	HI	HI																					
<b>OR GATE</b> 	<table border="1"> <thead> <tr> <th>1</th><th>2</th><th>3</th></tr> </thead> <tbody> <tr><td>LO</td><td>LO</td><td>LO</td></tr> <tr><td>LO</td><td>HI</td><td>HI</td></tr> <tr><td>HI</td><td>LO</td><td>HI</td></tr> <tr><td>HI</td><td>HI</td><td>HI</td></tr> </tbody> </table> 	1	2	3	LO	LO	LO	LO	HI	HI	HI	LO	HI	HI	HI	HI	Output is HI when any input is HI. Output is LO only when <u>all</u> inputs are LO.						
1	2	3																					
LO	LO	LO																					
LO	HI	HI																					
HI	LO	HI																					
HI	HI	HI																					
<b>NAND GATE</b> 	<table border="1"> <thead> <tr> <th>1</th><th>2</th><th>3</th></tr> </thead> <tbody> <tr><td>LO</td><td>LO</td><td>HI</td></tr> <tr><td>LO</td><td>HI</td><td>HI</td></tr> <tr><td>HI</td><td>LO</td><td>HI</td></tr> <tr><td>HI</td><td>HI</td><td>LO</td></tr> </tbody> </table> 	1	2	3	LO	LO	HI	LO	HI	HI	HI	LO	HI	HI	HI	LO	Output is LO only when <u>all</u> inputs are HI, otherwise output is HI.						
1	2	3																					
LO	LO	HI																					
LO	HI	HI																					
HI	LO	HI																					
HI	HI	LO																					
<b>NOR GATE</b> 	<table border="1"> <thead> <tr> <th>1</th><th>2</th><th>3</th></tr> </thead> <tbody> <tr><td>LO</td><td>LO</td><td>HI</td></tr> <tr><td>LO</td><td>HI</td><td>LO</td></tr> <tr><td>HI</td><td>LO</td><td>LO</td></tr> <tr><td>HI</td><td>HI</td><td>LO</td></tr> </tbody> </table> 	1	2	3	LO	LO	HI	LO	HI	LO	HI	LO	LO	HI	HI	LO	Output is LO when any input is HI. Output is HI only when <u>all</u> inputs are LO.						
1	2	3																					
LO	LO	HI																					
LO	HI	LO																					
HI	LO	LO																					
HI	HI	LO																					
<b>EXCLUSIVE OR GATE</b> 	<table border="1"> <thead> <tr> <th>1</th><th>2</th><th>3</th></tr> </thead> <tbody> <tr><td>LO</td><td>LO</td><td>LO</td></tr> <tr><td>LO</td><td>HI</td><td>HI</td></tr> <tr><td>HI</td><td>LO</td><td>HI</td></tr> <tr><td>HI</td><td>HI</td><td>LO</td></tr> </tbody> </table> 	1	2	3	LO	LO	LO	LO	HI	HI	HI	LO	HI	HI	HI	LO	Output is HI when <u>either but not both</u> inputs are HI, otherwise output is LO.						
1	2	3																					
LO	LO	LO																					
LO	HI	HI																					
HI	LO	HI																					
HI	HI	LO																					
<b>INVERTERS</b> 		The 2-input NAND or NOR gate can be used as inverters by tying one input to a fixed level or tying both inputs together.																					
<b>D-TYPE FLIP-FLOP</b> 	<table border="1"> <thead> <tr> <th>t = n</th><th>t = n + 1</th><th></th></tr> </thead> <tbody> <tr><td>D</td><td>Q</td><td>Q</td></tr> <tr><td>LO</td><td>LO</td><td>LO</td></tr> <tr><td>LO</td><td>HI</td><td>LO</td></tr> <tr><td>HI</td><td>LO</td><td>HI</td></tr> <tr><td>HI</td><td>HI</td><td>HI</td></tr> </tbody> </table>  <p>Truth Table valid only when <math>S_D</math> and <math>R_D</math> are both HI</p>	t = n	t = n + 1		D	Q	Q	LO	LO	LO	LO	HI	LO	HI	LO	HI	HI	HI	HI	When both $S_D$ (direct set) and $R_D$ (direct reset) are HI, level at input D is transferred to output Q when input C (clock) goes HI. A LO on $S_D$ forces Q HI and $\bar{Q}$ LO. A LO on $R_D$ forces $\bar{Q}$ HI and Q LO. $S_D$ and $R_D$ predominate over all other inputs.			
t = n	t = n + 1																						
D	Q	Q																					
LO	LO	LO																					
LO	HI	LO																					
HI	LO	HI																					
HI	HI	HI																					
<b>J-K MASTER SLAVE FLIP-FLOP</b> 	<table border="1"> <thead> <tr> <th>t = n</th><th>t = n + 1</th><th></th></tr> </thead> <tbody> <tr><td>J</td><td>K</td><td>Q</td></tr> <tr><td>LO</td><td>LO</td><td>NO CHANGE</td></tr> <tr><td>LO</td><td>HI</td><td>LO HI</td></tr> <tr><td>HI</td><td>LO</td><td>HI LO</td></tr> <tr><td>HI</td><td>HI</td><td>HI LO</td></tr> <tr><td>HI</td><td>HI</td><td>LO HI</td></tr> </tbody> </table>  <p>Truth Table valid only when CLR is HI</p>	t = n	t = n + 1		J	K	Q	LO	LO	NO CHANGE	LO	HI	LO HI	HI	LO	HI LO	HI	HI	HI LO	HI	HI	LO HI	When CLR is HI and: 1. J and K are both LO, clock pulse has no effect on outputs Q and $\bar{Q}$ . 2. J and K are at opposite logic levels, negative-going clock edge transfers J level to Q and K level to $\bar{Q}$ . 3. J and K are both HI, each negative-going clock edge alternates outputs Q and $\bar{Q}$ . 4. LO on CLR forces and holds Q LO and $\bar{Q}$ HI.
t = n	t = n + 1																						
J	K	Q																					
LO	LO	NO CHANGE																					
LO	HI	LO HI																					
HI	LO	HI LO																					
HI	HI	HI LO																					
HI	HI	LO HI																					

## 2. CIRCUIT DESCRIPTION

### 2-1. THE POWER SUPPLY

2-2. The power supply for GT-10 is a bit more complicated than in previous games because additional voltages are needed to operate new circuitry. The normal +5 volts is still used to power most of the ICs; however, the ROM requires -12 volts and the hybrids need -5 volts and -12 volts. The +18 volt source is used only to drive the audio amplifier.

2-3. The four circuits which generate the different voltages are very similar. See Figure 2-1. First, the 110 VAC line voltage is stepped down by the transformer(s) to 32 VAC and 16 VAC. These secondary voltages are then processed by the on-board power supply components to generate the DC supplies.



TP 1: OSCILLOSCOPE: 32 VAC  
VOM/VTVM: 32 VAC

TP 2: OSCILLOSCOPE: 16 VAC  
VOM/VTVM: 16 VAC

TP 3: OSCILLOSCOPE: + 18 VDC  
VOM/VTVM: + 18 VDC

TP 4: OSCILLOSCOPE: + 11V PEAK  
VOM/VTVM: + 8.5 VDC

TP 5: LOGIC PROBE: High  
OSCILLOSCOPE: + 5 VDC  
VOM/VTVM: + 5 VDC

TP 6: OSCILLOSCOPE: - 18 PEAK  
VOM/VTVM: - 15.5 VDC

TP 7: OSCILLOSCOPE: - 12 VDC  
VOM/VTVM: - 12 VDC

TP 8: OSCILLOSCOPE: - 5 VDC  
VOM/VTVM: - 5 VDC

TP 9: OSCILLOSCOPE: - 0.6 VDC  
VOM/VTVM: - 0.6 VDC

TP 10: OSCILLOSCOPE: - 1.0 VDC  
VOM/VTVM: - 1.0 VDC

TP 11: LOGIC PROBE: High pulse when the start switch is operated.  
OSCILLOSCOPE: High pulse when the start switch is operated.

Figure 2-1. The Power Supply and Buffered Start



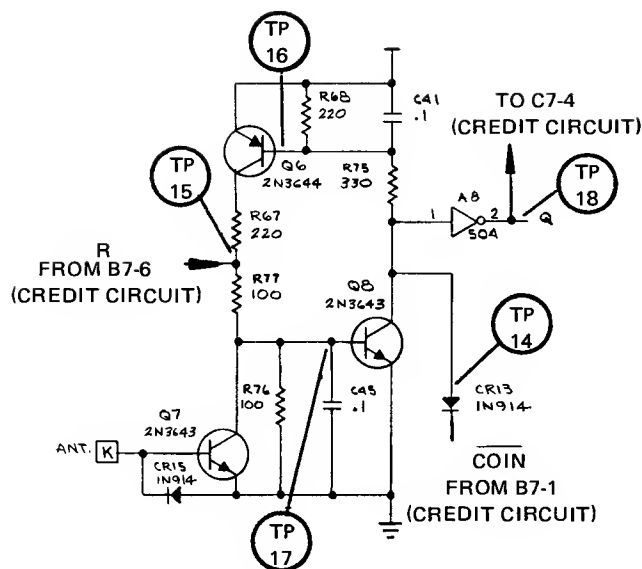


Figure 2-3. The Electronic Latch

TP 14:	LOGIC PROBE:	High going low when coin switch is operated.
	OSCILLOSCOPE:	Same as Logic Probe.
TP 15:	LOGIC PROBE:	High during game and low at game over.
	OSCILLOSCOPE:	Same as Logic Probe.
TP 16:	OSCILLOSCOPE:	+5 volts until coin switch is operated; then drops to approximately +1 volt.
TP 17:	OSCILLOSCOPE:	0 volts until coin switch is operated, at which time it rises to +.8 volts and remains there until game over.
TP 18:	LOGIC PROBE:	High during game mode; low during attract mode.
	OSCILLOSCOPE:	Same as Logic Probe.

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2-17. R is the credit signal from B7-6 in the credit circuit. A low R drags the base of Q8 low and, since Q8 can no longer conduct, the latch cycle is broken. This toggles the attract flip-flop and resets the computer to the ATTRACT mode.

2-18. The same type of process is used to prevent players from gaining free game credit by inducing a static charge in the machine. When a large enough static charge is discharged to the machine, the antenna wire picks up the necessary current to create a high at the base of Q7. This causes Q7 to conduct and the low at its collector turns off Q8 and breaks the latch cycle.

## 2-19. THE CREDIT AND START CIRCUIT

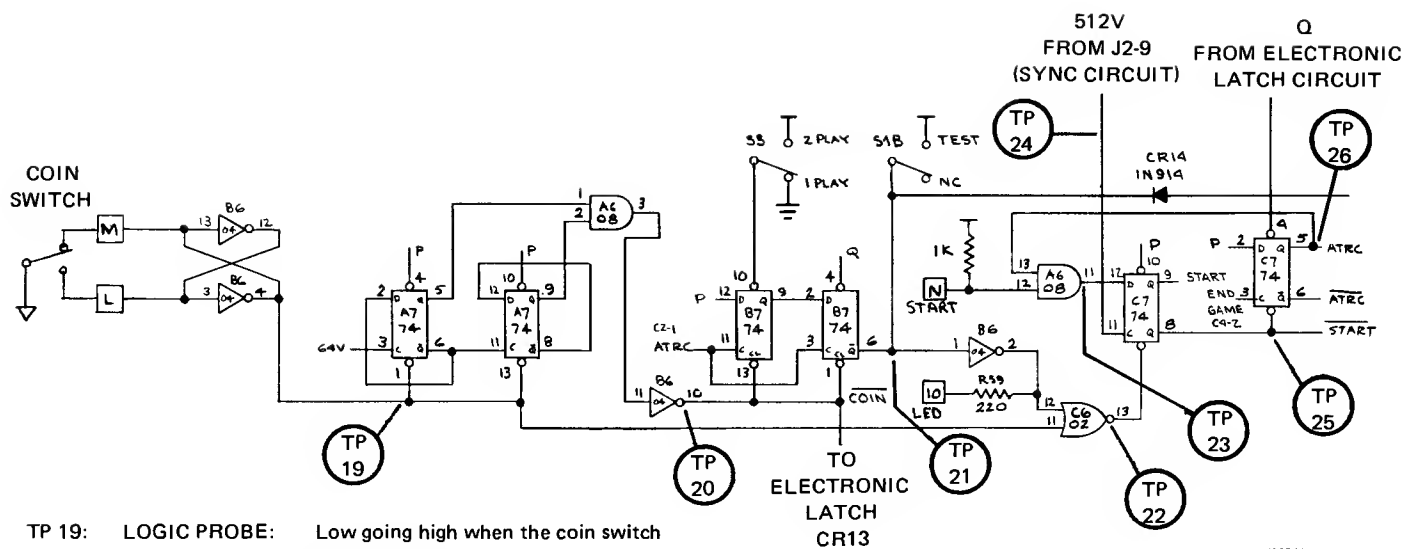
2-20. The credit portion of this circuit records the deposit of the coin and lights the credit lamp (LED). This provides game credit to the start circuit which is operated by the player to reset the PCB and begin the new game. The circuit is shown in Figure 2-4.

2-21. The deposited coin closes the normally-open side of the coin micro-switch, and the outputs of this switch are inverted by a debouncing circuit consisting of the two B6 inverters. The debouncing circuit eliminates undesired impulses created by the chattering of the coin switch contacts. The debouncing circuit outputs enter the clear inputs of flip-flops A7. These two flip-flops constitute an anti-cheat device, designed so that incidental or player-induced vibrations which may operate the coin switch trip wire will not produce game credit. In order to get the correct outputs from the A7 flip-flops, the coin switch contacts must make

for at least 128 horizontal sync pulses, or about 9 milliseconds. Since most incidental or player-induced vibrations produce a coin switch make of only a few microseconds, the Q outputs of the flip-flops will not go high and no game credit will result.

2-22. However, if a coin is deposited, both A7 flip-flops are enabled, and when both of the Q outputs are high, pin 3 of AND gate A6 will also go high. This produces a low at pin 10 of inverter B6 which clears both B7 flip-flops. If the 1P/2P switch (1 play or 2 plays per coin) is set to the 1P mode, the preset input (pin 10) of B7 is held low and when  $\overline{\text{COIN}}$  returns high, a high will appear at the Q output (pin 9) of B7. However, if the switch is set to the 2P position, when  $\overline{\text{COIN}}$  goes low, the Q output (B7-9) will go low and stay low until the high at the D input (B7-12) is clocked through by the ATRC signal. A low also appears at the Q output (B7-6) which is inverted at B6-2 and lights the credit LED. The same signal which cleared the B7 flip-flops ( $\overline{\text{COIN}}$ ) also drags the collector of transistor Q8 low and turns on the electronic latch (see Figure 2-3) which enables the attract flip-flop C7 at pin 4. Since the credit lamp must be lighted to enable gate C6, and since C6 enables the start flip-flop C7, the game cannot be started unless the credit lamp is lighted.

2-23. When the START switch is operated, pin 12 of AND gate A6 is pulled high by its 1K pull-up resistor, and since the ATRC line (A6-13) is already high, pin 11 of A6 will go high. This produces a high at the D input of start flip-flop C7 at pin 12. Since the clock input of this flip-flop is connected to vertical sync at 512V (J2-9), the high at the D input will be clocked out when 512V goes high and this is the START signal. Meanwhile,  $\overline{\text{START}}$  goes low and



TP 19: LOGIC PROBE: Low going high when the coin switch is operated.  
OSCILLOSCOPE: Same as Logic Probe.

TP 20: LOGIC PROBE: High before coin switch is operated and high, low and pulsing while switch is held in the operated position.  
OSCILLOSCOPE: High before coin switch is operated and high with low-going pulses 4.6 ms wide occurring every 12.5 ms while coin switch is held in the operated position.

TP 21: LOGIC PROBE: Low before coin switch is operated and high thereafter until game over.  
OSCILLOSCOPE: Same as for Logic Probe.

TP 22: LOGIC PROBE: Low going high when coin switch is operated.  
OSCILLOSCOPE: Same as Logic Probe.

TP 23: LOGIC PROBE: Low going high when the start switch is operated. Stays high during game.  
OSCILLOSCOPE: Same as Logic Probe.

TP 24: LOGIC PROBE: Low and pulsing.  
OSCILLOSCOPE: High pulses 0.28 ms wide occurring every 16.7 ms.

TP 25: LOGIC PROBE: High with a low going pulse when the start switch is operated.  
OSCILLOSCOPE: Same as Logic Probe, except note that the low-going pulse is about 15 ms.

TP 26: LOGIC PROBE: High during attract mode and low during game mode.  
OSCILLOSCOPE: Same as Logic Probe.

Figure 2-4. The Credit and Start Circuit

clears C7 at pin 1. This produces a low at the attract flip-flop output which returns to shut off gate A6 at pin 13, thereby starting the game and locking out the start switch so the player cannot reset the computer during the game and gain additional time.

## 2-24. TV MONITOR OPERATION

2-25. It is important that you understand the basics of TV monitor operation so that you can later comprehend how the signals generated by the PCB computer are synchronized with the operation of the monitor. We will not dwell on how the monitor receives and displays the information other than to say the electron beam illuminates spots on the phosphorescent coating of the CRT per the PCB signal information. What is critical is how these PCB signals are timed with the operation of the electron beam.

2-26. This type of TV monitor directs its electron beam in a fashion known as true interlaced raster scan. The TV screen picture (or raster) is composed of 260.5 horizontal lines stacked on top of one another. The electron beam always scans this raster whether or not it is receiving any PCB signals. The PCB signals simply modulate the electron beam so that spots of different intensity are illuminated. To see what this raster looks like, disconnect the PCB edge connector and turn the monitor brightness all the way up. The pattern of horizontal lines you see is the raster.

2-27. The electron beam begins its sweep in the top left-hand corner of the CRT and sweeps one horizontal line which ends at the right-hand side of the CRT. The electron beam is then repositioned at the left-hand side of the CRT prior to sweeping the next line. The process of moving the beam from the right side back to the left is known as hori-

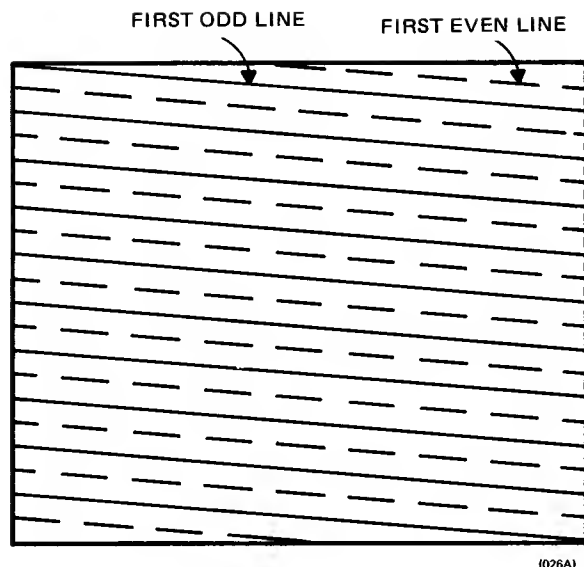


Figure 2-5. Interlaced Raster Scan

zontal retrace and the beam must be blanked out (horizontal blanking) during retrace so no undesired illumination occurs.

2-28. The electron beam skips the second line, sweeps the third, is blanked out, sweeps the fifth line and so on. When the beam has swept all the odd numbered lines it is said to have completed one odd field. After completing the odd field, the beam is in the bottom right corner of the CRT. In order to begin the even sweep, it must be repositioned in the top center of the CRT where the first even line begins. The process of moving the beam vertically to the top of the screen is known as vertical retrace and, of course, the beam must be blanked out (vertical blanking) during vertical retrace.

2-29. The beam sweeps a full field of all the even numbered lines in the same fashion as it completed the odd field. This system of sweeping the odd lines first and then the even lines is known as interlacing. Two completely interlaced fields (one even and one odd) constitute one full frame. The electron beam sweeps the CRT at the rate of 30 frames per second.

## 2-30. SYNCHRONIZATION AND BLANKING

2-31. A complex system of synchronization is required so the video signals generated by the PCB computer modulate the electron beam when the beam is in the correct part of the CRT. The essence of synchronization is timing. When sync is malfunctioning, the images appear to shift and move about the CRT because they are displayed in a different place each frame. The PCB signals must synchronize with the electron beam horizontally so that the information on each line is displayed in the proper sequence (and also vertically so that the vertical positioning of the images is correct). The sync pulses "tell" the electron beam when to start and stop its sweep, but do not otherwise control the raster. The sync circuit signals are also used in many other places in the PCB to time other operations with the TV monitor.

2-32. The basic timing for the horizontal sync circuit is the clock frequency. Vertical sync, however, runs off of horizontal sync. The horizontal and vertical sync counters count-down the clock pulses to form timed pulse trains (see Figure 2-6). The electron beam begins its sweep when horizontal reset (H RESET) goes low; this occurs after 451 clock pulses are counted out by the horizontal sync counters. The rising edge of the next H RESET pulse occurs

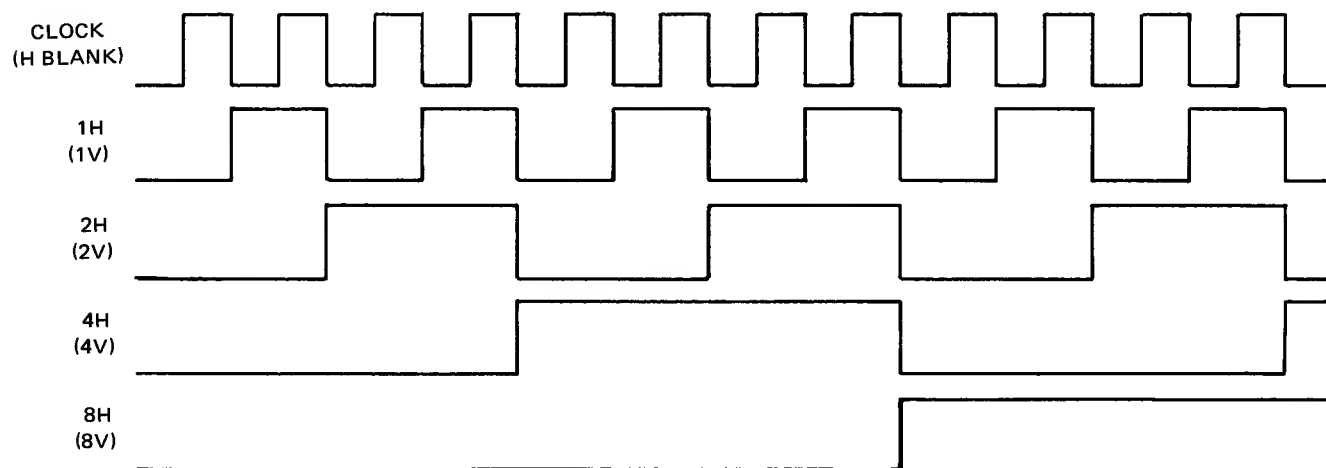
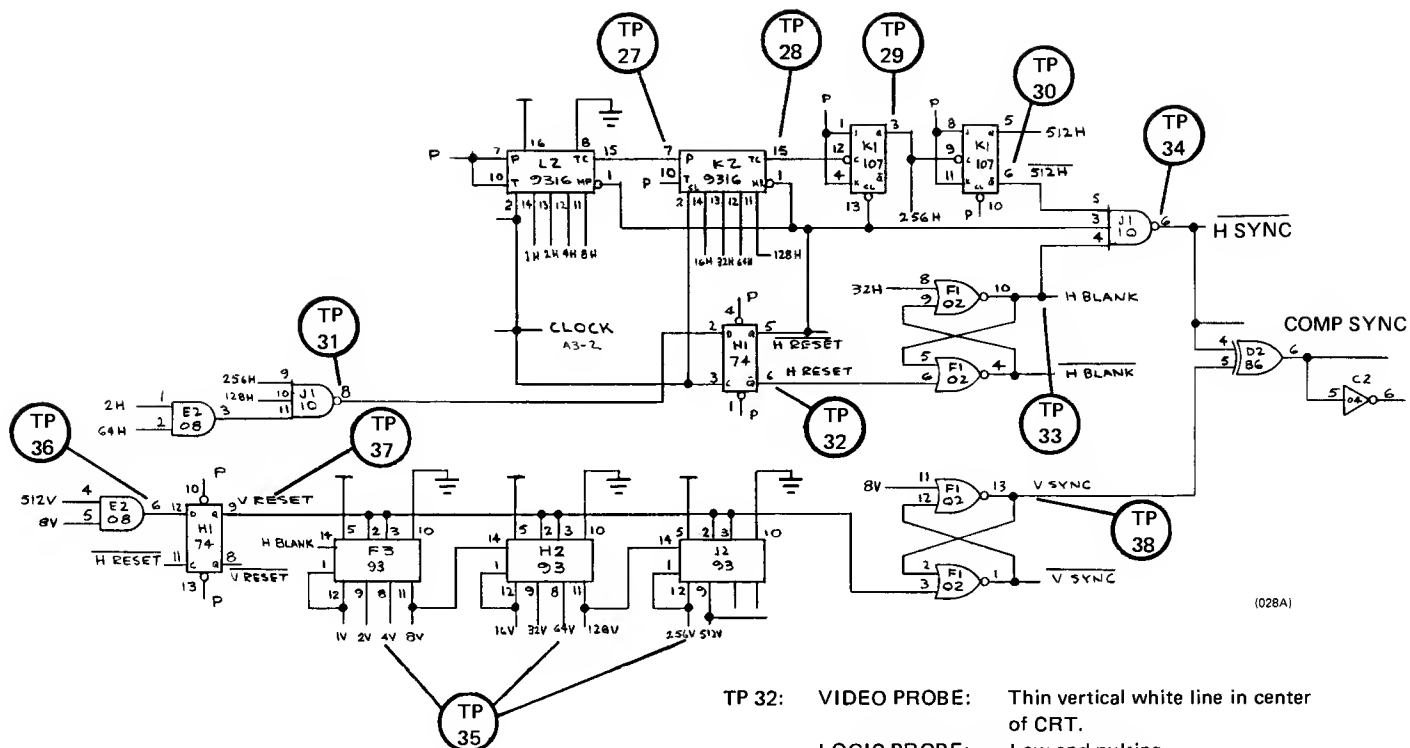


Figure 2-6. Sync Pulse Trains

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<p>TP 27: VIDEO PROBE: A number of thin vertical white lines.          LOGIC PROBE: Low and pulsing.          OSCILLOSCOPE: High pulses 0.07 ms wide and occurring every 1.12 ms.</p>	<p>TP 32: VIDEO PROBE: Thin vertical white line in center of CRT.          LOGIC PROBE: Low and pulsing.          OSCILLOSCOPE: High pulses 0.1 ms wide and occurring every 32 ms.</p>
<p>TP 28: VIDEO PROBE: Two vertical white bands.          LOGIC PROBE: Low and pulsing.          OSCILLOSCOPE: High pulses 1.3 ms wide and occurring every 32 ms.</p>	<p>TP 33: VIDEO PROBE: White vertical band in center of CRT.          LOGIC PROBE: Low and pulsing.          OSCILLOSCOPE: High pulses 2.3 ms wide occurring every 33 ms.</p>
<p>TP 29: VIDEO PROBE: Alternating black and white bands.          LOGIC PROBE: High, low and pulsing.          OSCILLOSCOPE: Low pulses 14 ms wide and occurring every 32 ms.</p>	<p>TP 34: LOGIC PROBE: High and pulsing.          OSCILLOSCOPE: Low pulses 2.3 ms wide occurring every 64 ms.</p>
<p>TP 30: VIDEO PROBE: Left half of CRT black; right half white.          LOGIC PROBE: High, low and pulsing.          OSCILLOSCOPE: Symmetrical square wave with a 64 ms period.</p>	<p>TP 35: VIDEO PROBE: Starting with 2V, touch probe to all outputs up to 512V. Notice that the horizontal black and white bars double in width at each successive division.</p>
<p>TP 31: VIDEO PROBE: One thin vertical black line in center of CRT.          LOGIC PROBE: High and pulsing.          OSCILLOSCOPE: Low pulses 0.1 ms wide and occurring every 32 ms.</p>	<p>TP 36: LOGIC PROBE: Low and pulsing.          OSCILLOSCOPE: High pulses 20 ms wide occurring every 16.7 ms.</p>
<p>TP 32: VIDEO PROBE: Thin vertical white line in center of CRT.          LOGIC PROBE: Low and pulsing.          OSCILLOSCOPE: High pulses 0.1 ms wide and occurring every 32 ms.</p>	<p>TP 37: LOGIC PROBE: Low and pulsing.          OSCILLOSCOPE: High pulses 30 ms wide occurring every 16.7 ms.</p>
<p>TP 33: VIDEO PROBE: White vertical band in center of CRT.          LOGIC PROBE: Low and pulsing.          OSCILLOSCOPE: High pulses 2.3 ms wide occurring every 33 ms.</p>	<p>TP 38: LOGIC PROBE: Low and pulsing.          OSCILLOSCOPE: High pulses 0.25 ms wide occurring every 16.7 ms.</p>

Figure 2-7. Synchronization and Blanking

when the electron beam reaches the right-hand side of the CRT, and the beam is reset back to the left-hand side by the monitor.

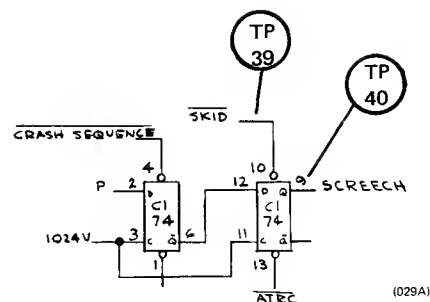
2-33. H RESET resets the sync counters after 451 clock pulses or counts. This is the end of the line (which actually occurs in the middle of the screen) so the counters must be started again. Horizontal blanking (H BLANK) is initiated by H RESET and lasts for 32 clock pulses. During this time information to be displayed in the next line is loaded into many parts of the PCB. The final horizontal sync signal (H SYNC) is composed of both H RESET and H BLANK and tells the electron beam when to start and stop its sweep.

2-34. Vertical reset serves the same purpose as H RESET except it occurs after 521 horizontal blanking pulses (or half lines) when the electron beam is in the lower right-hand corner of the CRT. There is no vertical blanking signal because no information needs to be loaded during vertical reset. The vertical sync signal serves the same purpose as H SYNC except it is timed to the vertical operation of the monitor.

2-35. The sync signals are generated in the following manner (see Figure 2-7). The clock starts L2 counting, and when L2 reaches TC (terminal count), TC goes high and stays high for one clock pulse. Since TC of L2 is connected to CEP (count enable parallel) of K2, when TC of L2 goes high, K2 is advanced by one count by the clock pulse at pin 2. K2 then counts 15 clock pulses and then TC of K2 goes high (after a total of 255 clock pulses). The falling edge of the 256th clock pulse causes K1-3 to go high and it will stay high until the 451st clock pulse when it is reset by H RESET. This 256H is divided again at K1-5 producing the 512th clock pulse or count which is the line that divides the CRT in half.

2-36. H RESET is an output of H1 and it is created by the addition of 256H, 128H, 64H and 2H and the result of J1-8 is a pulse 2H wide and 450 clock pulses from the last H RESET pulse. This is clocked through H1 by CLOCK producing the H RESET signal. Horizontal blanking is generated by H RESET which sets the RS flip-flop composed of the F1 gates. This causes H BLANK to go high and 32 clock pulses later it resets the RS flip-flop producing a blanking pulse 32 clock pulses wide after the H RESET pulse. Horizontal blanking is then gated with H RESET and 512H to produce H SYNC.

2-37. Vertical reset is generated by horizontal blanking which clocks counter F3 at pin 14. The counter divides the clock frequency by eight and the output of this counter goes to H2 where it is again divided eight times. The result-



- TP 30: LOGIC PROBE: High until brake switch is closed, then drops low.  
OSCILLOSCOPE: Same as Logic Probe.
- TP 40: LOGIC PROBE: Low going high when brake switch is closed.  
OSCILLOSCOPE: Same as Logic Probe.

Figure 2-8. Screech Logic

ing signal is finally divided another four times by counter J2. J2 is allowed to divide only to four (a count of 512) because on the 521st count (512 plus 8V plus one more H RESET pulse) all the counters are reset by V RESET. Vertical sync is created by RS flip-flop which is set by V RESET and reset by 8V. This produces a high sync pulse which is four lines wide.

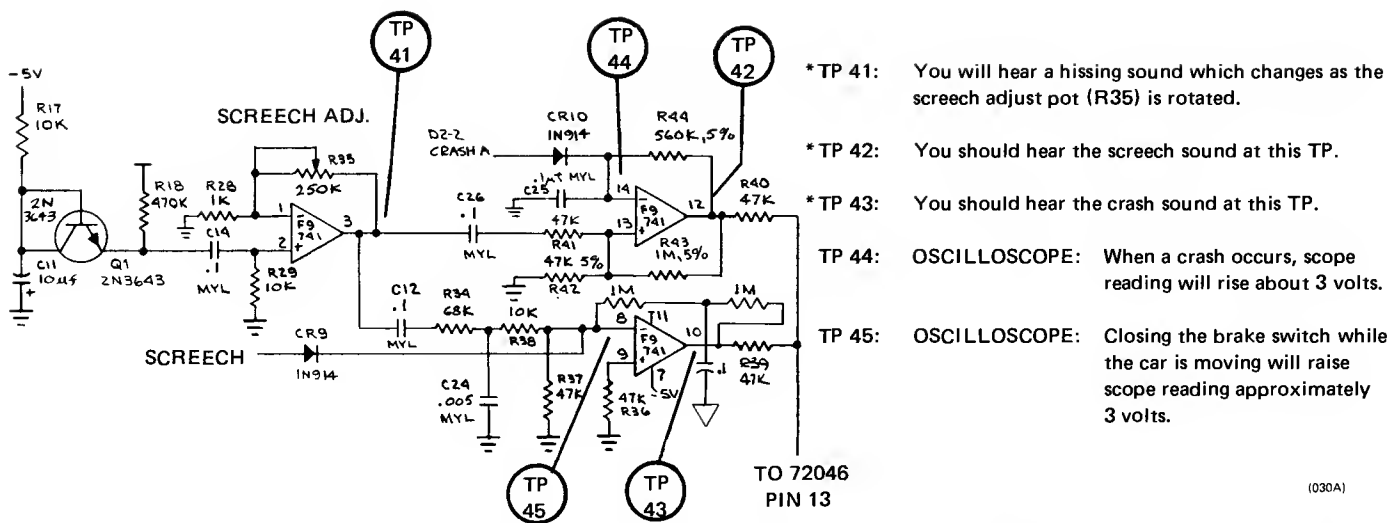
2-38. Because there are an odd number of half-lines being counted out, the electron beam must start at the center of the top of the screen every other field to achieve vertical reset. This is why the first line of the even field begins in the center of the CRT.

## 2-39. SCREECH LOGIC

2-40. This circuit (see Figure 2-8) generates the SCREECH signal, which creates the "screech" sound through the screech sound generator, and through the 8103 of the speed control circuit. ATTRACT must be high (a game started) to enable the screech circuit. If SKID (the "brakes applied" signal) goes low presetting flip-flop C1, the SCREECH signal will go high. When SKID returns high, 1024V will be clocked through two frames later turning the SCREECH signal off.

## 2-41. SCREECH AND CRASH SOUND GENERATION

2-42. This circuit creates the screech and crash sound signals which eventually wind up in the audio amplifier where they are amplified so that they can be transformed into audible sounds by the speaker. The screech sound occurs when the brakes are applied (while the car is moving),



\*NOTE: To check test points 41 – 43, make a “noise probe” by connecting your video probe from capacitor C8 (in audio amp circuit) to TPs 41 – 43. If you hear the following sounds, the sound generator is O.K. although adjustment of R35 may be indicated. Volume of noise probe TPs may be adjusted with the volume pot.

Figure 2-9. Screech and Crash Sound Generator

and the crash sound results from a collision between the car and any one of the race course pylons. Both signals go through the 8103 hybrid before reaching the audio amplifier.

2-43. Refer to Figure 2-9. Transistor Q1 is the actual noise generator, and the signal from Q1 is amplified by F9-3. Trim pot R35 varies the feedback threshold of amplifier F9 which limits the number of “noise spikes” allowed through F9-3, thereby adjusting the quality of the screech and crash sounds. When the brake switch is closed and the car is moving,  $\overline{\text{SKID}}$  is enabled.  $\overline{\text{SKID}}$  presets flip-flop C1 in the screech logic and the SCREECH output at pin 9 goes high. When SCREECH goes high, the crash sound operational amplifier is shut off at F9-8 allowing only the screech sound to reach the 8103. The screech sound is always being generated except when disabled by CRASH A. If a crash occurs, CRASH A goes high which disables the screech amplifier at F9-14 allowing only the crash sound through to the 8103.

#### 2-44. ENGINE RPM SOUND GENERATION

2-45. This circuit creates the sounds of the car engine both when it is idling and when it is moving. This is accomplished with three function generators and one electronic attenuator. See Figures 2-10 and 2-11.

2-46. When ATTRACT is high (during the attract mode), Q3 conducts and holds pins 5 of C8, D8 and E8 above ground potential disabling these function generators.

When a game is started, ATTRACT drops low and these function generators are enabled. Closing the gas pedal switch drops the RPM signal voltage from 0 volts to about -4 volts, which causes the function generators to modulate the frequencies of their signals.

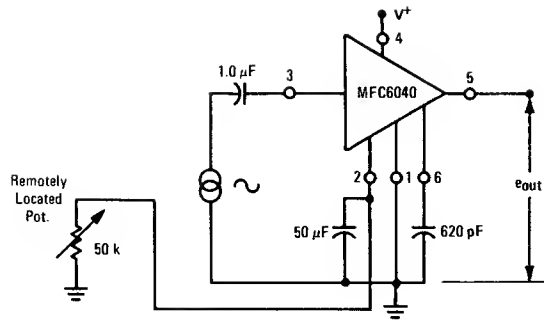
2-47. The sound signals from C8 and D8 are the inputs to the attenuator (F8), and the signal from E8 modulates the amplitude of the attenuator output. The resulting sound signal is carried to the audio amplifier and then to the speaker. Note that each 566 function generator is individually adjustable by trim pots R60, R55, and R50. See Figure 2-11 for adjustment details.

#### 2-48. THE AUDIO AMPLIFIER

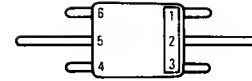
2-49. An audio amplifier is necessary to drive the speaker. See Figure 2-12. The sound signals enter the amplifier circuit through R16 and C8. The resistance of R4 determines the gain (the volume) and is adjusted by turning the small blue trim pot (marked “volume”) found near the LM 380. The LM 380 is a transistor operated device which amplifies the sound signal to a level high enough to drive the speaker.

#### 2-50. SPEED CONTROL

2-51. This circuit uses three custom chips (8103, 8098 and 8099) which have been specifically designed for Gran



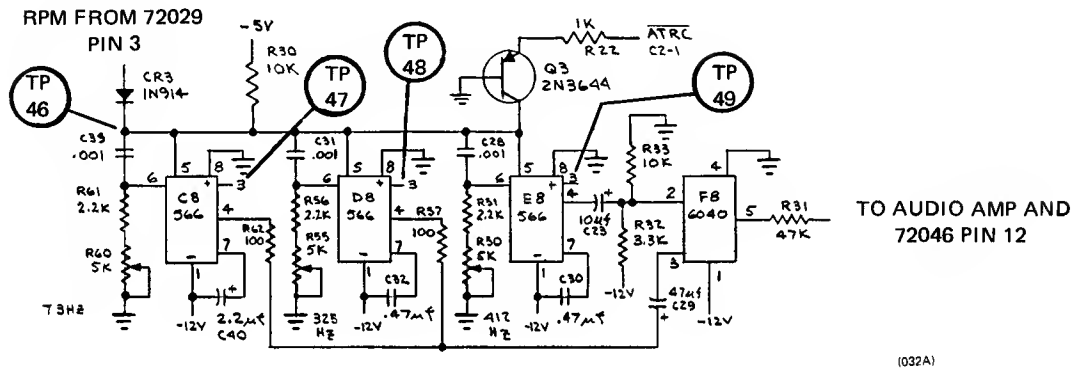
a. Schematic



(031A)

b. Pin Configuration

Figure 2-10. Electronic Attenuator



(032A)

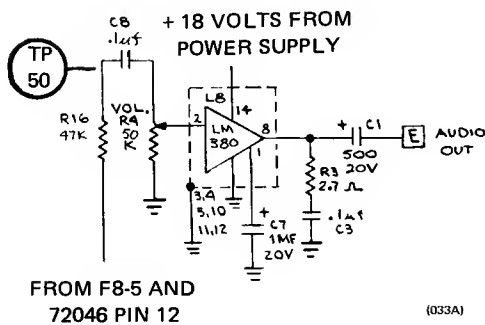
TP 48: OSCILLOSCOPE: When R55 is correctly adjusted, you will see a 3.07 ms square wave.

TP 46: OSCILLOSCOPE: Closing the gas pedal switch causes the RPM signal voltage to drop from 0 to -4 volts.

TP 49: OSCILLOSCOPE: When R50 is correctly adjusted, you will see a 7.42 ms square wave.

TP 47: OSCILLOSCOPE: When R60 is correctly adjusted, you will see a 13 ms square wave.

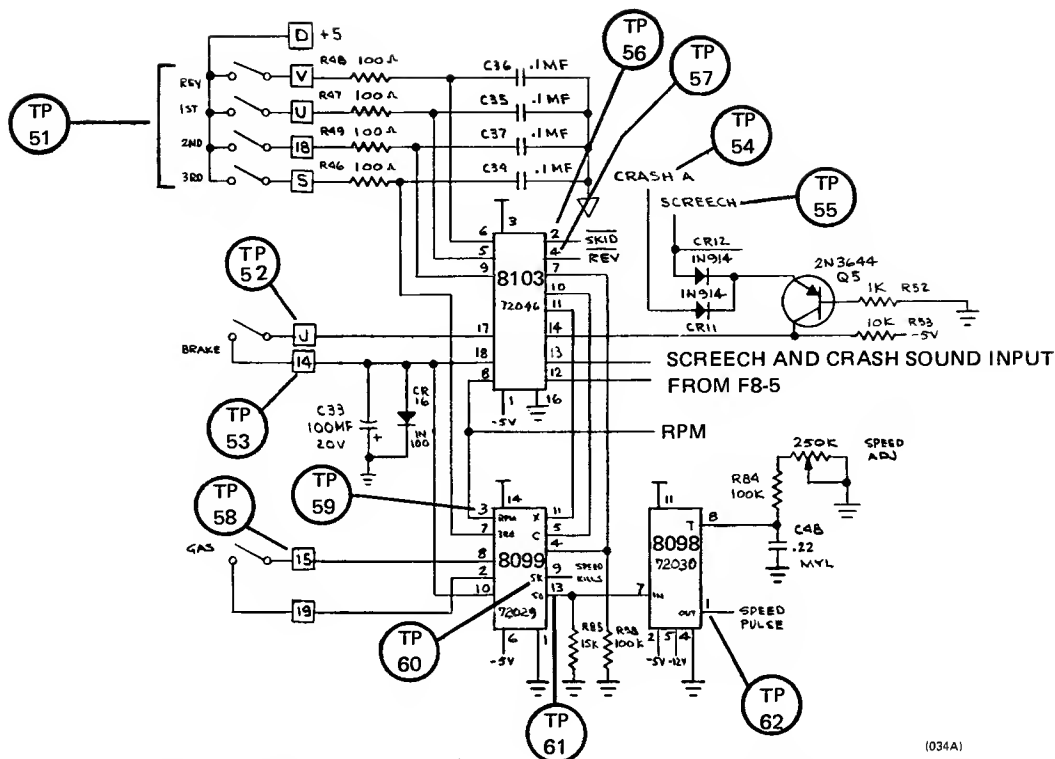
Figure 2-11. Engine RPM Sound Generator



(033A)

TP 50: Use the "noise probe" method to test the audio amplifier. Turn the volume down, attach the clip end of a video probe to capacitor C8 and run the prod down the vertical sync counter outputs. You will hear a series of tones from counter pins H2-12, 9, 8 and 11.

Figure 2-12. The Audio Amplifier



TP 51: LOGIC PROBE: Low going high as each shift switch is closed.

OSCILLOSCOPE: Same as Logic Probe.

TP 52: OSCILLOSCOPE: - 5 volts rising to + 2 volts when the brake switch is closed or a crash occurs.

VTVM: Same as Oscilloscope.

TP 53: Check voltage drop with the Oscilloscope or voltmeter as you reach top speed in each gear.

Reverse . . . . . - 0.8 volts

1st gear . . . . . - 0.8 volts

2nd gear . . . . . - 1.7 volts

3rd gear . . . . . - 3.5 volts

TP 54: LOGIC PROBE: Low going high when a crash occurs.

OSCILLOSCOPE: 0 volts rising to + 3.5 volts at crash.

VTVM: Same as Oscilloscope.

TP 55: LOGIC PROBE: Low going high when brake switch closed.

OSCILLOSCOPE: 0 volts rising to + 3.5 volts when brake switch is closed.

TP 56: LOGIC PROBE: High going low when brake switch is closed.

OSCILLOSCOPE: Same as Logic Probe.

TP 57: LOGIC PROBE: High going low when gearshift is in reverse.

OSCILLOSCOPE: Same as Logic Probe.

TP 58: Check with Oscilloscope or voltmeter. Voltage should drop from + 5 volts to the indicated values as you reach top speed in each gear.

Reverse . . . . . + 2.5 volts

1st gear . . . . . + 2.5 volts

2nd gear . . . . . + 2.5 volts

3rd gear . . . . . + 4.3 volts

TP 59: Check with Oscilloscope or voltmeter. Voltage should drop from 0 volts to the indicated values as you reach top speed in each gear.

Reverse . . . . . - 3.7 volts

1st gear . . . . . - 3.7 volts

2nd gear . . . . . - 3.8 volts

3rd gear . . . . . - 4.3 volts

TP 60: LOGIC PROBE: Low when car is at rest; high when car crashes.

OSCILLOSCOPE: Same as Logic Probe.

TP 61: Check with Oscilloscope or voltmeter. Voltages should drop from 0 volts to indicated values as you reach top speed in each gear.

Reverse . . . . . - 0.5 volts

1st gear . . . . . - 0.5 volts

2nd gear . . . . . - 1.2 volts

3rd gear . . . . . - 2.6 volts

TP 62: LOGIC PROBE: Low when car at rest; low and pulsing when car is moving.

OSCILLOSCOPE: Following readings are to be taken with car at top speed in each gear.

Reverse . . . . . 56 ms between pulses.

1st gear . . . . . 58 ms between pulses.

2nd gear . . . . . 35 ms between pulses.

3rd gear . . . . . 16 ms between pulses.

Figure 2-13. Speed Control

Trak 10 and are available only through Atari, Inc. If one of these chips should fail, order a replacement by the part number on the chip itself. The speed control circuit controls the car speed, the engine RPM sound and the screech and crash sounds. Refer to Figure 2-13 for the following discussion.

#### NOTE

Schematic chip numbers 8103, 8099 and 8098 correspond to actual chip numbers 72046, 72029 and 72030.

**2-52. 8103/72046 Input/Output Conditions:** When any one of the shift switches is closed, the line connected to that switch goes high. Three of these switches (reverse, 1st and 2nd) are connected to pins 5, 6 and 9 of the 8103, and the 3rd gear switch is connected to pin 7 of the 8099. Closing these switches eventually controls the SPEED PULSES output from the 8098 as you will see under the discussion of the 8098.

**2-53.** The screech and crash sound signals enter the 8103 at pin 13. Pin 12 is the sound output. When the brake pedal switch is closed, SKID (pin 2) goes low and the SCREECH signal goes high. SCREECH disables the crash sound generator which allows only the screech sound through to the 8103. The screech sound is enabled through the 8103 by the closing of the brake switch, and continues to come out until capacitor C33 completely discharges through pin 17.

**2-54.** When a crash occurs, CRASH A goes low disabling the screech sound and allowing only the crash sound to reach the 8103. Both the screech and the crash sounds are controlled by the input to pin 14 which rises from -5 volts to +2.5 volts if you crash or step on the brake. So when a crash occurs, only the crash sound is enabled through the 8103. REV (reverse not) at pin 4 goes low whenever the reverse shift switch is closed. This signal goes to C2-9 (steering encoder circuit) and then to the ROM address multiplexers to control the direction of the car image.

**2-55. 8099/72029 Input/Output Conditions:** Pins 2 and 8 of the 8099 are connected to the gas pedal switch and control the acceleration of the car. When the car is stationary or in gear with no gas, pin 8 will be +5 volts. When you step on the gas, this will drop to approximately 2.4 volts in first and second gears and rise to 4 volts in third. Pin 2, on the other hand, is at 0 volts when the car is stationary or in gear with no gas. When in first or second gear with the gas switch closed, pin 2 will rise to about +2.4 volts and will rise to 4 volts in third gear with the gas pedal depressed.

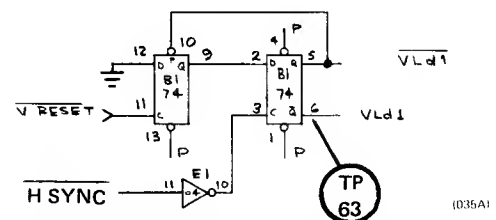
**2-56.** Pin 3 (RPM) is at 0 volts when the gas switch is open, and drops to about -3.8 volts when you step on the gas in first. When you shift into second, pin 3 rises to approximately -2 volts and then drops to about -3.8 volts as the car picks up speed. When you shift into third, it rises to -2 volts again and drops down to about -4.2 volts when the car reaches maximum speed. Top speed in reverse should produce about -3.8 volts at pin 3.

**2-57.** Pin 13 is the input to the 8098 Speed Pulse Generator. Pin 13 starts at 0 volts and drops to -0.5 volts at top speed in first gear. When you shift into second, it rises to about -2 volts and drops to about -3.8 volts as the car picks up speed. When you shift into third, it rises to -2 volts again and then drops down to about -4.2 volts when the car reaches maximum speed. Closing the reverse switch causes pin 13 to drop from 0 volts to -0.5 volts.

**2-58. 8098/72030 Input/Output Conditions:** As pin 7 of the 8098 drops lower and lower, the speed pulses from pin 1 increase in frequency. This frequency is adjustable by the SPEED ADJUST pot R84 (see Section 1 for more details on this adjustment). The input to pin 9 of the 8099 comes from D5-8 (the crash circuit) and is used to disable the speed pulses during the attract mode or during a crash. This pin must go high to disable.

#### 2-59. VLd1

**2-60.** VLd1 (vertical load one) is used to address the ROM for the vertical positioning of the car image. Refer to Figure 2-14. V RESET clocks the low from B1-12 out the Q output and this low waits at B1-2 until it is clocked through by H SYNC. The Q output (B1-5) presets B1-9 causing a high to appear at B1-9. This high is clocked through to B1-5 on the next H SYNC pulse. The result is a VLd1 pulse which occurs once per field and is one H SYNC pulse wide.



**TP 63:** LOGIC PROBE: Low and pulsing.  
OSCILLOSCOPE: High pulse 63.5 ms wide occurring every 16.7 ms.

Figure 2-14. VLd1

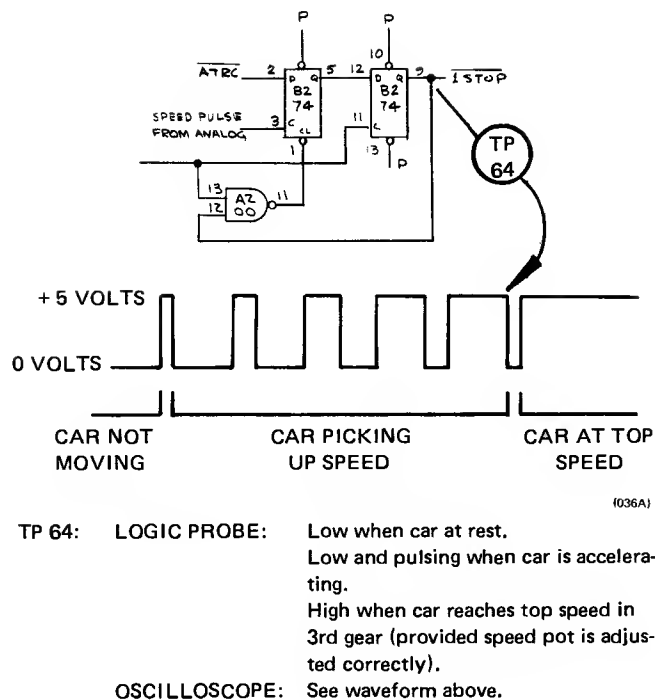


Figure 2-15.  $\overline{1\text{ STOP}}$

## 2-61. $\overline{1\text{ STOP}}$

2-62. This signal is a ROM address which determines the speed with which the car image is moved. The input to this circuit (see Figure 2-15) is SPEED PULSE from pin 1 of the 8098 in the speed control circuit. As the car picks up speed, the speed pulses increase in frequency. When the car is stationary,  $\overline{1\text{ STOP}}$  is low. As the car starts moving,  $\overline{1\text{ STOP}}$  begins pulsing high and the pulses get closer together and longer in duration until the car reaches top speed in third gear, at which time the signal stays high.

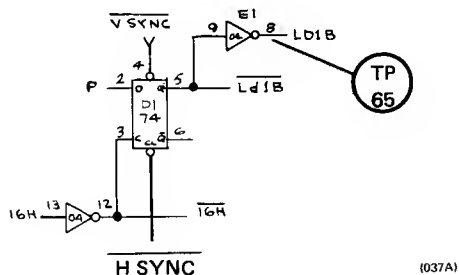


Figure 2-16. Ld1B

## 2-63. Ld1B

2-64. Ld1B (load one B) is another ROM address; however, it is also used in several other places to load information into counters, etc. See Figure 2-16.  $\overline{H\text{ SYNC}}$  clears flip-flop D1. Sixteen clock pulses later, the high is clocked from the D input out the Q output and is inverted to become Ld1B.  $\overline{V\text{ SYNC}}$  disables this function once per field, producing a wider Ld1B pulse.

## 2-65. RESET 1

2-66. The function of this signal is to tell the car motion circuits where to reposition the car image at the start of a new game or after the car is driven off the race course. When CAR 1 VIDEO encounters  $\overline{\text{COMPOSITE SYNC}}$  (i.e., the car is driven off the screen), A2-6 goes low causing a low to appear at A6-6 and this low clears flip-flop A4. The flip-flop remains cleared until it receives the next  $\overline{VLd1}$  pulse which clocks the high from A4-2 out A4-5 and this signal is known as  $\overline{\text{RESET 1}}$ .  $\overline{\text{START}}$  serves a similar function in the circuit as the low from A2-6 in that it also clears RESET 1.

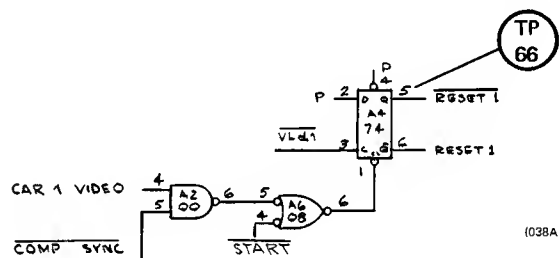


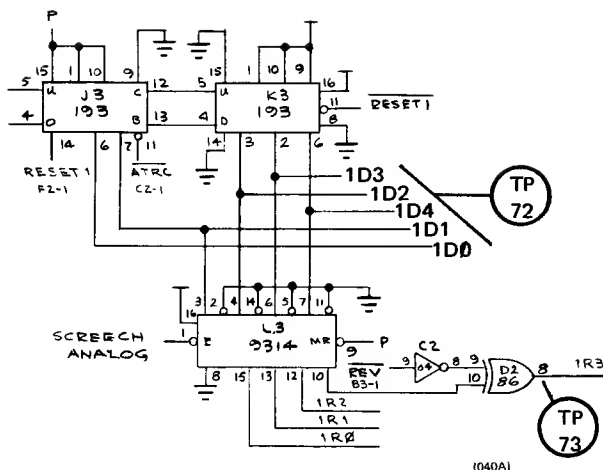
Figure 2-17. RESET 1

## 2-67. STEERING CONTROL

2-68. The Steering Control circuit is shown in Figure 2-18. The two infrared light emitting diodes (LEDs) mounted on the steering assembly PCB are aimed directly at the two phototransistors and, as the slotted steering ring rotates, the path of light is broken up causing the phototransistors to pulse in a way which corresponds to the direction of the steering wheel rotation. These pulses are fed into four-input Schmitt triggers (J8) which clean up the pulses so the flip-flops can be triggered consistently.

2-69. When the steering wheel is turned in a clockwise direction, a rising edge occurs at the clock input of K8 before a rising edge reaches the D input. This causes the CW





- TP 72: LOGIC PROBE: Changes state twice per each complete car image revolution.  
OSCILLOSCOPE: Same as Logic Probe.
- TP 73: LOGIC PROBE: The signal from L3-10 will change state when REV goes low.  
OSCILLOSCOPE: Same as Logic Probe.

Figure 2-19. Steering Encoder

at J3-12. This advances K3 which then produces another binary code at its output pins 2, 3, and 6. However, if the DOWN input to J3 is pulsed, J3 will count down from the last loaded number and, when it reaches 0, a borrow pulse is generated at J3-13 which decrements K3.

2-75. At the beginning of the game, or if the car is driven off the track, RESET goes low. This resets the counters to zero and re-orientes the car image. L3 is a latch which takes the 1D1, 1D2, 1D3 and 1D4 outputs from the counters and passes these signals on to the ROM multiplexers unless SCREECH is high. A high SCREECH latches up the last information from the counters and holds it until SCREECH goes low again. This causes the car image to continue moving in the same direction it was going when the brakes were applied, even if the steering wheel is turned which produces a realistic "slide" or "drift".

2-76. REV at C2-9 selects and inverts the most significant digit from L3, causing the car to back up in the opposite direction the car image was oriented in when the gear-shifter was placed in reverse. This is necessary to produce a realistic back-up sequence.

## 2-77. CRASH AND PLAYTIME

2-78. This circuit has several functions: (1) it generates the crash signal when the car is driven into the pylons, (2) it

times the length of the game, and (3) it incorporates the TEST switch which is used to turn off the playtimer and crash mode when testing the board. See Figure 2-20 for the following discussion.

2-79. The 555 timer at B8 is the component which actually provides the timing. The amount of time it takes to charge C43 determines the pulse width out of the 555, and controls the period of time the output signal, 1 SEC, is high. R72 adjusts both the crash time period and the playtime by varying the amount of time required to charge the capacitor. The timer output is used to clear the crash flip-flops after a crash has occurred. It is also the input to the game timer circuit which turns the game off after it counts a certain number of 1 SEC pulses. If the TEST switch is in the normal position, the 555 is allowed to produce the high 1 SEC pulses. However, if the switch is set to the TEST position, pin 4 of the 555 is grounded out and the game timer cannot count down.

2-80. This circuit also generates the crash signal (CRASH A) whenever the car window encounters the race track signal by gating the two signals together at D5-3. A crash produces a low at D5-3 which clears both B5 flip-flops and 2048V later, a low is clocked out B5-8. During the time B5-8 is high, flip-flop C5 is enabled and asks the question, "Is there a car on the pylons?" If the answer is "no" (i.e., one of the wheels has just barely glanced off a pylon), C5 continues to repeat the question until it is cleared at pin 13 by a low from B5-8. However, if the answer to C5's question is "yes", C5-8 goes low causing D5-11 to go high and the "yes" information is latched into C5 at pin 5 producing a high at CRASH A and a low at CRASH A. A low CRASH A produces a low SPEED KILL signal from D5-8 which stops the car motion. A low ATRC will also produce a low SPEED KILL and stop the car whenever the computer is in the attract mode.

## 2-81. THE MEMORY CIRCUIT

2-82. This circuit stores information which is later read out for the generation of the car image, the race track display and the score and timer displays. The main components are four multiplexers and one 16K ROM which has been specially programmed for Gran Trak 10 (See Figure 2-21).

2-83. The ROM is a memory unit which stores binary information. This information is read out of the ROM by the multiplexers, and these outputs go to other circuits where the information is used to form the different aspects

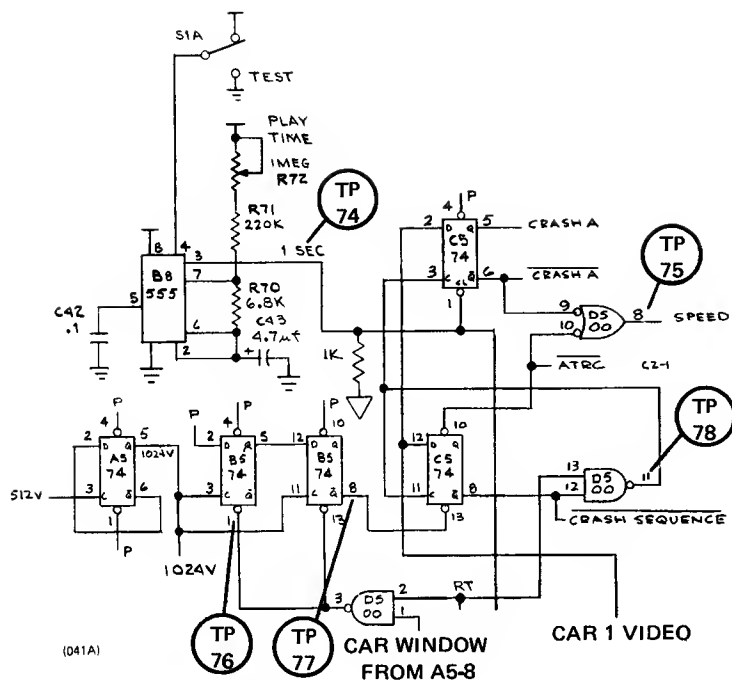


Figure 2-20. Crash and Playtime

- TP 74: LOGIC PROBE: High with low pulses approximately once per second when TEST switch is in the play mode. Frequency of 1 SEC is adjustable by R72.
- OSCILLOSCOPE: Same as Logic Probe.
- TP 75: LOGIC PROBE: High going low when the car crashes.
- OSCILLOSCOPE: Same as Logic Probe.
- TP 76: LOGIC PROBE: Drops low when the car encounters the race track.
- OSCILLOSCOPE: Same as Logic Probe.
- TP 77: LOGIC PROBE: High pulse when the car crashes.
- OSCILLOSCOPE: Same as Logic Probe.
- TP 78: LOGIC PROBE: Normally high, low and pulsing; changes to high when a crash occurs.

of the car image, the race track display, etc. The ROM stores 2048 eight-bit words. Multiplexers select certain signals from a larger input of signals and these output signals are the "addresses" for the ROM. A different multiplexer address is required to read out each different eight-bit ROM word. For example, when information is needed for the generation of the car image, the multiplexers select the correct ROM address, and this selected signal reads out the desired car image information from the ROM. This ROM information is then fed into the car motion circuits and a new aspect of the car image is displayed on the CRT.

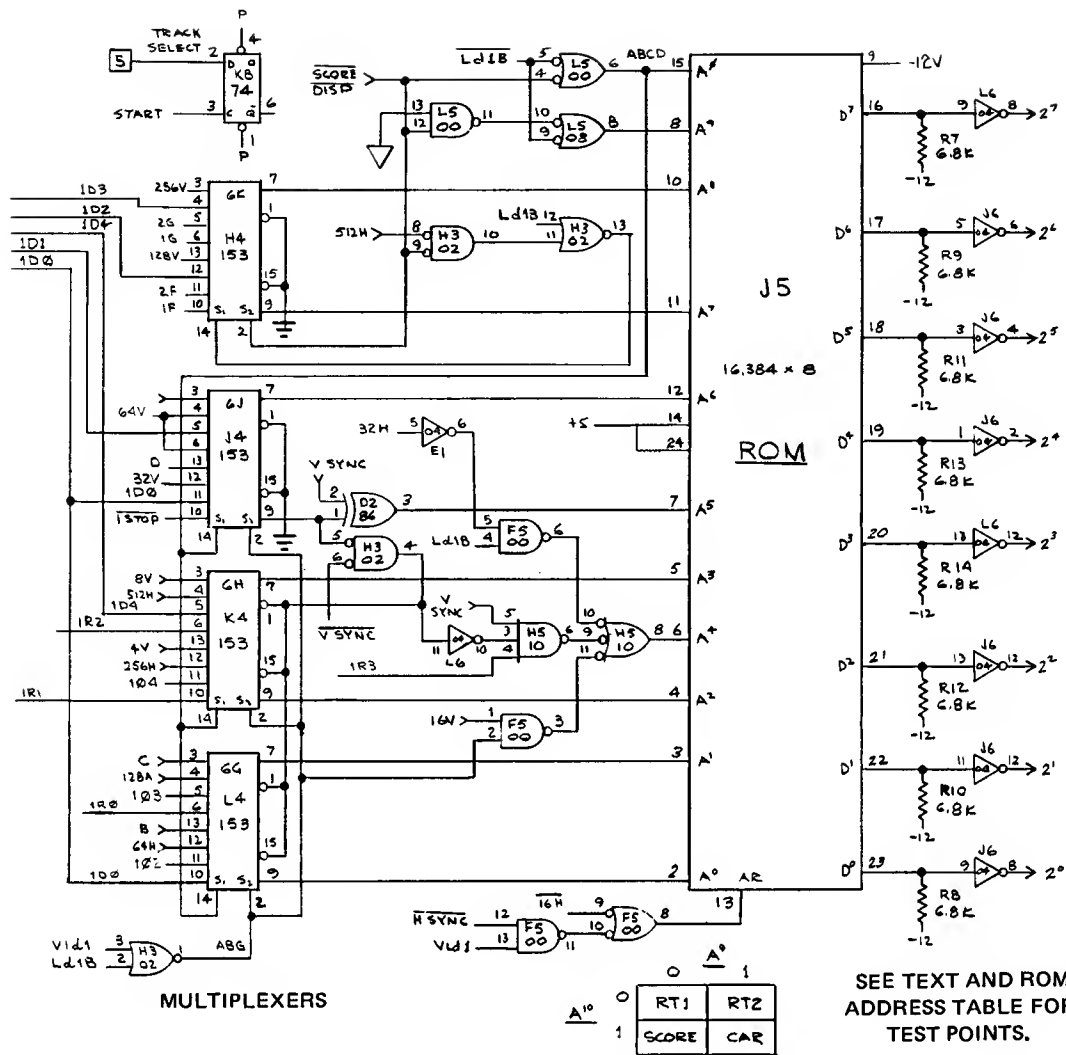
2-84. It is important to understand how the multiplexers function, so we have included a brief discussion of basic multiplexer operation. Figure 2-22 is the schematic of a basic two-input two-to-one data multiplexer. When the data select line (S) is high, the signal at the A input is reflected at the output and not A. The multiplexers used to address the ROM are nothing more than elaborations of the foregoing theme. The ROM requires multiplexers which can select one of two four-bit words.

2-85. The ROM itself is not a particularly complicated device; it is useful only because it can store so much information in a small space. You can visualize the ROM being constructed from 2048 rows of 8 diode gates each, where each gate is connected to one of the eight ROM outputs. Each diode in every row is specially programmed so that it reads out either a high or a low when it is addressed. Each

row of eight gates must be addressed by a different binary number. Since there are 2048 rows, the ROM requires a ten-bit address input. When this number is read out by the multiplexers into the ROM address input, each diode in the selected row reads out its high or low to one of the ROM outputs.

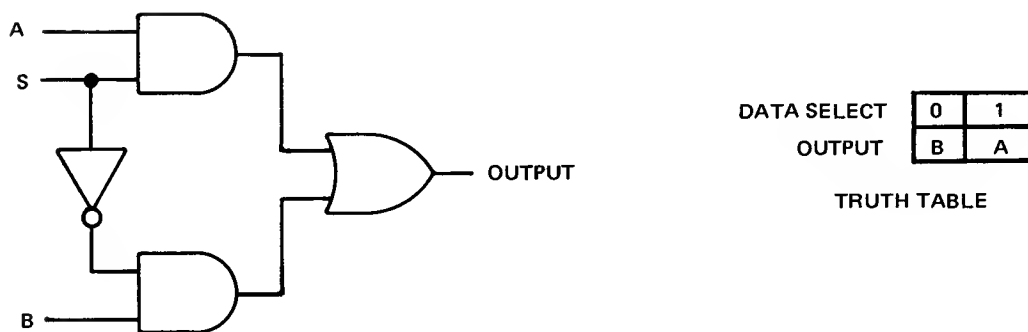
2-86. **Troubleshooting the Memory Circuit:** Some typical symptoms of malfunctions in this circuit are a distorted or missing car image, portions of the race track distorted or missing or distortion of the lap counter or game timer displays. If you suspect trouble in this section, the first step is to replace the ROM. A plug-in type receptacle has been provided to facilitate replacing the ROM. If the malfunction disappears, leave the new ROM in. However, the ROM failure rate is extremely low, so if a new ROM does not fix the problem, go on to the following troubleshooting procedures.

2-87. If the ROM is OK, next check the ROM addresses at ROM inputs  $A^0 - A^9$ . If these addresses are not OK, check the inputs to the multiplexers, the multiplexed outputs and any gating which may be between the multiplexer outputs and the ROM inputs. The ROM address table (Table 2-1) is invaluable in troubleshooting this section. We will use a car image problem to demonstrate the use of the address table. To find the correct address for the car image at the ROM inputs, look under the column labeled "CAR A". Then clip the scope probe to the device the ROM information is to be read into, which is shift register F6. The



(042A)

Figure 2-21. The Memory Circuit



(043A)

Figure 2-22. Basic Two-Input Two-to-One Multiplexer

Table 2-1. ROM Address Table

CAR A	SCORE C	TIME D	1 R.T. E	2 R.T. F	SPEED CODE G	ROM ADD	MULTIPLEX ADD
1	1	1	0	0	0	A0	
1	0	0	0	1	1	9	
1D3	1G	2G	256V	256V	256V	8	A+C+D+EFG
1D2	1F	2F	128V	128V	128V	7	A+C+D+EFG
1D1	1E	2E	64V	64V	64V	6	A+C+D+EFG
1D0	1D	2D	32V	32V	0G0 1 STOP	5	A+C+D+EF+G
32H*	16V	16V	16V	16V	1R3 0 STOP	4	A+C+D+EF+G
1D4	8V	8V	512H	512H	1R2	3	A+CD+EF+G
104	4V	4V	256H	256H	1R1	2	A+CD+EF+G
103	1C	2C	128H	128H	1R0	1	A+C+D+EF+G
102	1B	2B	64H	64H	1D0	0	A+C+D+EF+G

\* 32H-1 FIRST PART OF CAR  
- 0 SECOND PART OF CAR

probe would be placed on the pin which is used to control when the data will be entered; in this case it is the shift load input (S/L) at pin 1. When the shift load pin goes low, the information will be loaded into the register. Then take the second probe and check the ROM address inputs and compare these with the information at the multiplexer inputs. Finally, compare all of this information with the table.

2-88. For example, first check ROM address A<sup>0</sup> (pin 15) with the second probe and you should see a high pulse occurring at the same time as the low shift load pulse. Note that this correctly corresponds to the ROM address table. Then look at A<sup>9</sup> (pin 8) and again there should be a high pulse occurring simultaneously with the low shift load pulse. Now go to A<sup>8</sup> and you should see signal 1D3 which will pulse high and low as the steering wheel is rotated. Continue to check all the address inputs in the same fashion. If you find some information which does not correctly correspond, start checking back through the multiplexers and gates (if any). If all the information checks out OK, examine the component that information is being loaded into (shift register F6 in this case).

2-89. To troubleshoot the multiplexers, first check the multiplexer inputs. If any of these do not check out, go to the section which produces the malfunctioning signal and locate the malfunction there. However, if all the multiplexer inputs are OK, check the data select lines by going to gates H3 and L5 and verifying the presence of the correct

Ld1B, VLd1, 512H and SCORE DISP inputs. If all of the data select inputs are also OK, you must check the multiplexers themselves.

2-90. The multiplexers are most easily checked using a logic comparator (see paragraph 1-11). The comparator will yield fast and accurate results. If you do not have a comparator, use the following procedure: first tie both multiplexer select lines low and look at the information from pins 7 and 9 (multiplexed outputs) which must match the inputs at pins 6 and 10 (multiplexer inputs). If OK, tie S<sub>1</sub> high and S<sub>2</sub> low, and pins 7 and 9 should match 5 and 11. If OK here, tie S<sub>1</sub> low and S<sub>2</sub> high, and 7 and 9 should equal 4 and 12. To check the last set, tie both select lines high and pins 7 and 9 should match 3 and 13.

## 2-91. THE WINDOW CONCEPT

2-92. After the video signals are generated by the computer, they must be displayed on the desired part of the CRT. This is done by directing the signals to appear only within a certain area or "window". The key idea behind the window concept is that of limits or boundaries.

2-93. Your video probe is a test instrument which can be used to display the windows directly on the CRT. To see a graphic display of windows, attach one probe clip to the negative (—) side of the video coupling capacitor (C44) and

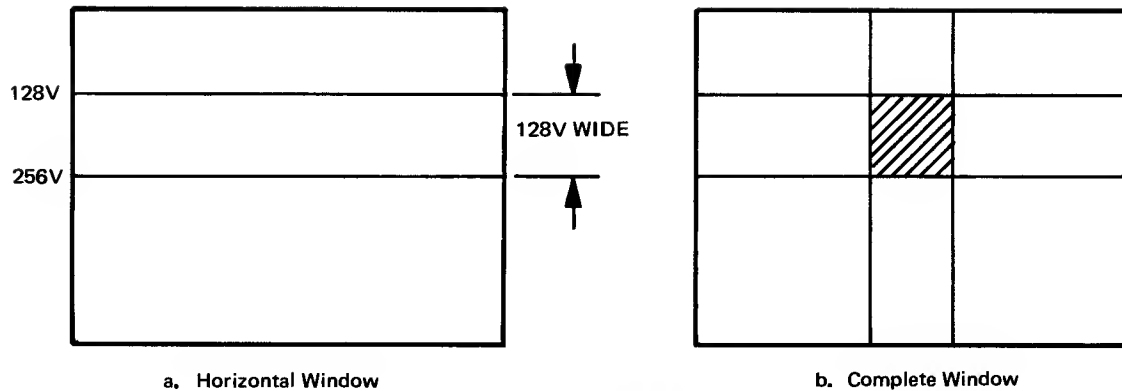


Figure 2-23. CRT Windows

(044A)

run the other end across the sync counter outputs. You probably noticed, as you ran the probe across the vertical sync outputs, that the resulting windows were horizontal in appearance. The most confusing part of the window concept is the fact that it takes vertical signals to define a horizontal window and vice versa.

2-94. Examine Figure 2-23a and notice the vertical signal 256V which defines a horizontal line approximately half way down the CRT. Since the raster is composed of 521 half lines (or 260.5 whole lines), the signal 256V "tells" the electron beam to modulate its scan at the 256th half line down from the top of the screen and the lower half of the screen is white. This is why it takes a vertical signal to define a horizontal line a certain vertical distance down the CRT. If we create a similar line, except 128 half lines down the CRT, the result will be a band 128 half lines wide bounded at the top by 128V and at the bottom by 256V. This band is known as a horizontal window.

2-95. A complete window (Figure 2-23b) is created by generating a similar vertical window and gating the two windows together, so that we have an area with all four sides defined. The video signals are gated with the window so that they can only appear when the window occurs. The result is that the video can then only appear within the window.

## 2-96. INTRODUCTION TO MOTION

2-97. The illusion of car motion is achieved by rapidly shifting the car image in the same way the illusion of motion is created on the motion picture screen by the film in the projector. The eye perceives this image shift as motion because of a phenomenon known as "retinal after-image". The last seen image is "remembered" for a short time and as the position of the image is shifted a number of times in rapid succession, the eye "overlaps" the images and perceives the shifting process as continuous motion. Since the TV monitor has a frame rate of 30/second, it is possible to shift the car image so rapidly that the eye is completely fooled.

2-98. The speed or velocity of the car image is determined by the shift-rate/frame-rate ratio. If the image is shifted once every frame it will appear to move much faster than if it were shifted only once every three frames. The direction of the image is controlled by varying the rate at which the car image windows are shifted with respect to each other. Notice the vertical motion window in Figure 2-24a. As this window moves up and down, the image contained within it also moves up and down. Figure 2-24b shows the horizontal motion window which controls how the image is shifted from left to right. When the two windows are combined, the image can be vectored at any angle by individually varying the rate each window is shifted.

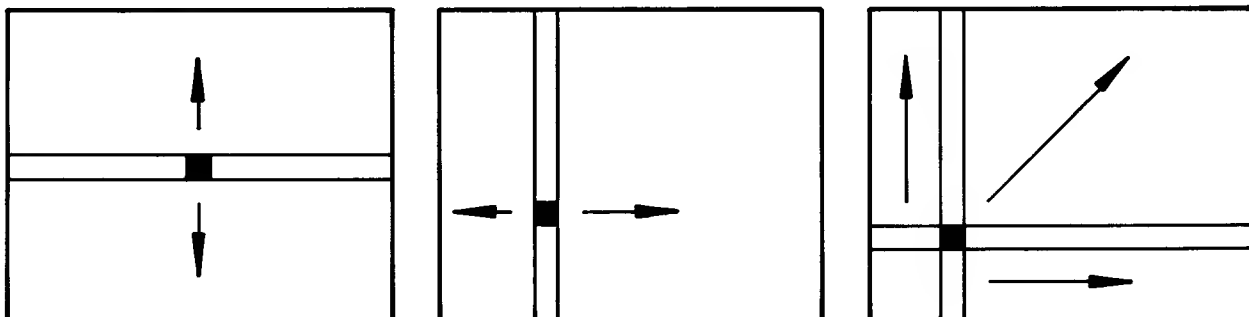


Figure 2-24. CRT Image Motion

(045A)

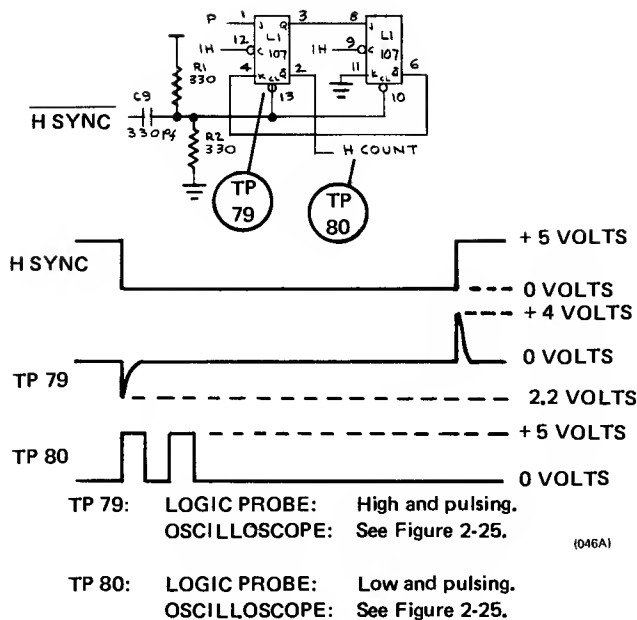


Figure 2-25. Horizontal Count

2-99. The speed of the image is controlled by shifting the window with respect to sync. If the window frequency is the same as sync, it will be displayed in exactly the same place during each TV frame and it will appear stationary. However, if the window is generated a little slower or faster than sync, it will be shifted a certain amount each frame and will appear to move. This is done by entering different binary codes at the parallel inputs to the 9316 counters of the motion circuits. The stop code is that binary number which times the window with sync and therefore stops motion. Other codes cause a change in this relationship and the window is shifted with respect to sync.

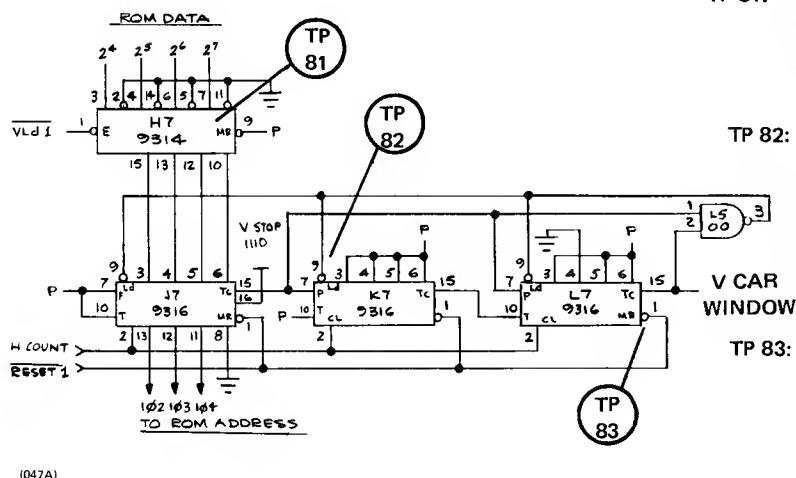


Figure 2-26. Vertical Car Motion

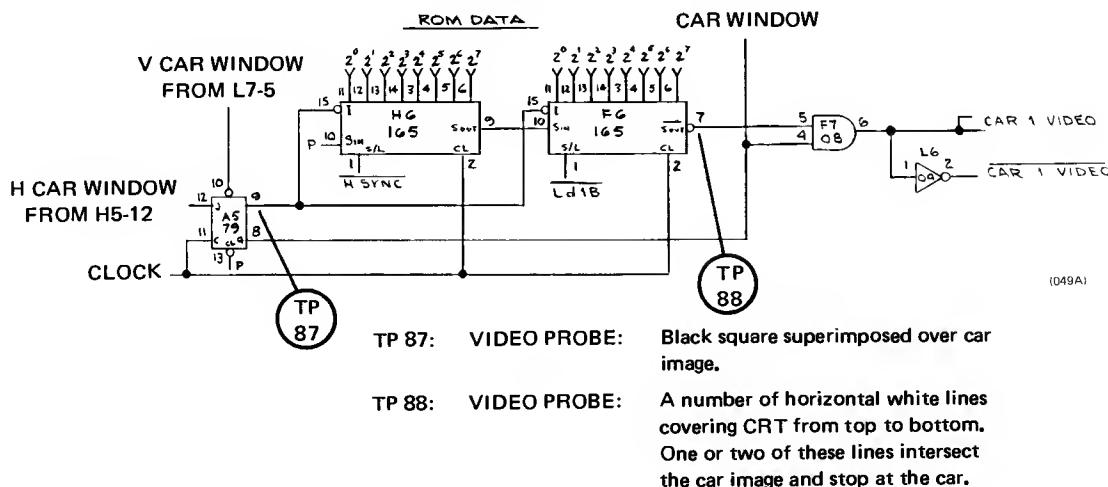
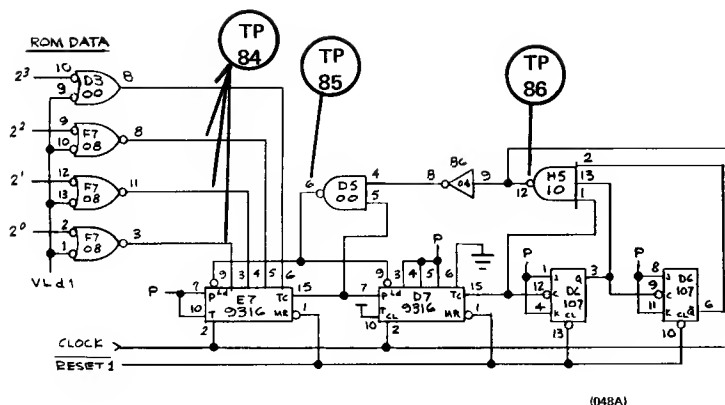
## 2-100. HORIZONTAL COUNT

2-101. H COUNT is used to clock counter J2 (vertical positioning for the car image) twice per line. See the circuit in Figure 2-25. Capacitor C9 and resistors R1 and R2 create a very short reset pulse for both L1 flip-flops and this produces a high at both Q outputs. On the first 1H pulse, the  $\overline{Q}$  output at L1-2 goes low while L1-3 goes high. The  $\overline{Q}$  at L1-6 remains unchanged. On the second 1H pulse, L1-2 goes high and L1-6 goes low. On the third 1H pulse, both L1-2 and L1-6 go low and stay low until both flip-flops are again reset by the capacitor and resistors.

## 2-102. VERTICAL CAR MOTION

2-103. The vertical car motion circuit is shown in Figure 2-26. When  $\overline{VLd1}$  is high, the ROM data is latched into H7 and appears at the outputs when  $\overline{VLd1}$  drops low again. This information is loaded into the parallel inputs of J7 when the line from L5-3 goes low. It takes 4096 H COUNT pulses to produce a low on this line. The counters start counting from the last number loaded in by L5-3 and count 4096 H COUNT pulses at which time a new number is loaded in.

2-104. The stop code for vertical motion is 3575 (1-1-1-0/1-1-1-1/1-0-1-1). When this number is entered into the counters, car motion ceases (4096 minus 3575 equals 521 which is the sync frequency). However, as the least significant digits of the stop code are changed, the 9316s begin their count from a different number and the resulting car window frequency is changed. For example, if the number 0-1-1-0 is loaded into J7, the window will move down at



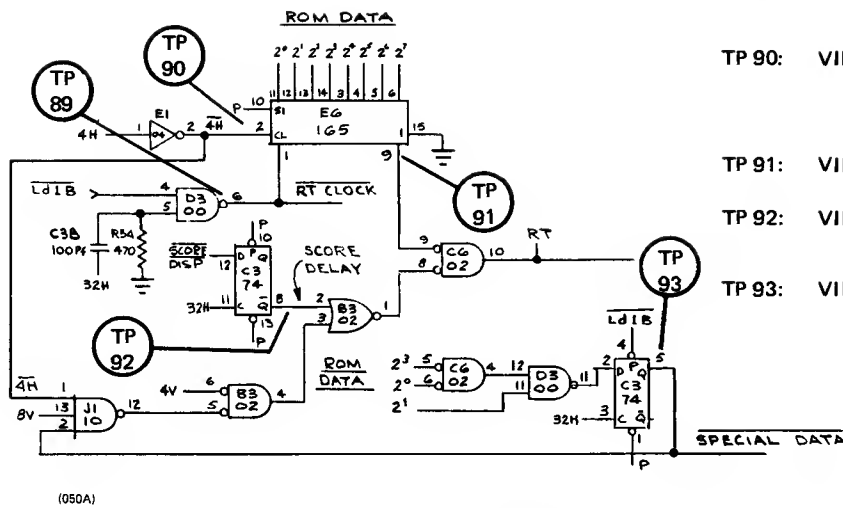


Figure 2-29. Race Track Display

the CRT. Two shift registers are needed because the car image is made up of 16 bits, and each shift register can only process 8 bits of information at a time.

2-110. The information is loaded at different times into the shift registers by  $\overline{H}$  SYNC and Ld1B. When  $\overline{H}$  SYNC and Ld1B both go low, one set of car information is loaded into H6 by  $\overline{H}$  SYNC and the register latches up this information when  $\overline{H}$  SYNC returns high. Ld1B is still low and another set of car information is loaded into F6 and latched up when Ld1B returns high. As long as the clock inhibit (1) of a shift register is high, the information remains latched in the register. However, when input 1 goes low, the clock pulses at pin 2 read out the information serially. The clock inhibit goes low during the car window signal which comes from the Q output of A5. The car window is the intersection of the vertical and horizontal car motion windows. So, when the inhibit inputs of the registers go low, F6 reads out its latched up information out pin 7 (the serial output) while H6 is simultaneously reading its information into F6. When all the information originally stored in F6 is read out F6-7, F6 then reads out the information read into it by H6. All this information is gated with the car window at F7 to form CAR 1 VIDEO which is the final car image signal.

## 2-111. RACE TRACK DISPLAY

2-112. The information for the generation of the race track display is read out of the ROM and this data is loaded into the parallel inputs of shift register E6 by RT CLOCK (see Figure 2-29). RT CLOCK is created at D3 by the gating of Ld1B with the modified 32H signal. The rising edge of 32H charges capacitor C38 which discharges through R54,

- TP 89: OSCILLOSCOPE: Low pulse 0.1 ms wide occurring every 4.5 ms except when Ld1B goes low.
- TP 90: VIDEO PROBE: Vertical 4H bars covering screen from left to right. NOTE: Wider band in center is due to reset pulse.
- TP 91: VIDEO PROBE: All race track windows visible.
- TP 92: VIDEO PROBE: White windows over score and timer displays.
- TP 93: VIDEO PROBE: Dark check point, finish line and non-delayed score and timer windows.

providing a very sharp high-going spike (there is also a low-going spike, but since it is below threshold voltage it cannot enable D3 and only the high-going spike is passed). This signal is gated with Ld1B, which allows only race track data to enter the shift register.

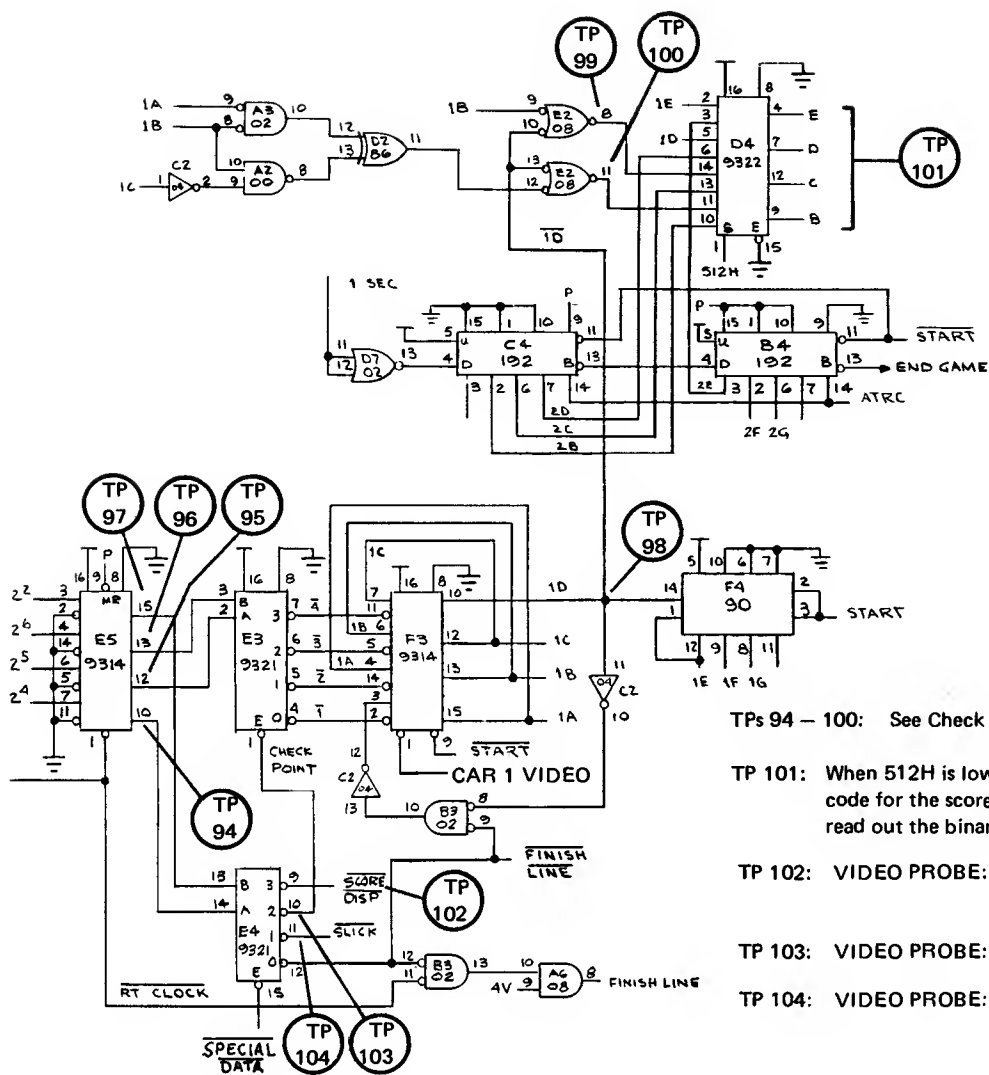
2-113. There are eight  $\overline{4H}$  pulses per each RT CLOCK pulse and the race track information is clocked out E6-9 serially by every 4H pulse. The resulting signal contains both the race track and the score information. Since the score window is generated at a different time than the score information is read out of the ROM, the score window (SCORE DISP) must be delayed at C3 by 32H so that the resulting score window occurs simultaneously with the score information and in the correct part of the CRT.

2-114. SPECIAL DATA prevents the race track data from being displayed when special information such as the finish line, the check points and the score need to be displayed. Otherwise, race track images would be "written over" the special data. Whenever  $2^0$  and  $2^3$  go low and while  $2^1$  and Ld1B are high, the special data is clocked out 32H later.

2-115. The sizes of the pylons and the check points are determined by J1 and B3. This information is gated with SCORE DELAY at B3 and then with the race track and score information at C6 to form the complete race track signal (RT).

## 2-116. TIME AND SCORE STORAGE

2-117. The primary functions of this circuit are to count the number of laps scored and the amount of elapsed time.



Laps are scored only by passing the race course check points in proper order. If the check points are passed correctly, the lap score is increased by an increment of two. The information needed for generating the score images is contained within the ROM and read out by the following process.

2-118. Refer to Figure 2-30. The ROM data at the parallel inputs of E5 are loaded into that latch when RT CLOCK goes low and is latched when RT CLOCK goes back high. The latched information enters the A and B inputs of the one-of-four decoders E3 and E4. The state of the E input controls the state of the selected output signal and the output signal is selected by the states of the A and B inputs. For example, if both A and B are low, output 0 will be selected and if E is low, the selected output 0 will also be low. If A is high and B is low, output 1 will be selected and if the E input is high, then output 1 will be high.

2-119. SPECIAL DATA (the signal from the race track display section which contains the data for score display, slick, finish line and the check points) is the E input to E4 and whenever SPECIAL DATA is low, the selected output of E4 will also be low. For instance, when the check point information is to be read out of the ROM, A will be low and B will be high which selects output 2 which will be low because E (SPECIAL DATA) is also low. Output 2 will then contain all the check point information which is then sequentially selected by E3.

2-120. Output 0 of E4 is the finish line signal; however, it is 64 clock pulses wide — too wide for a functional finish line so it is gated with RT CLOCK at B3. Since RT CLOCK is a spike of very short duration, the resulting finish line signal at B3-13 will also be of very short duration and appear as a thin line. This thin finish line is then chopped into segments by gating it with 4V at A6 to give it a "dotted line" effect.

2-121. Laps are scored only by passing course check points in the specified order and this is accomplished by selectively enabling latch F3. At the beginning of a new game, START goes high which clears F3 so it can accept new information. Clearing F3 produces lows at pins 15, 13, 12 and 10 (1A, 1B, 1C and 1D) and this causes lows to appear at pins 4, 6 and 7 and a high to appear at pin 3.

2-122. When the car passes through the first check point, the car signal at pin 1 will go high enabling the high at pin 3 to appear at pin 15 which goes around and holds pin 4 high. When the car passes through the second check point, the high at pin 4 will be enabled through to pin 13 and so on. This continues until the car has passed all the check points at which time 1D will go high incrementing counter F4 and

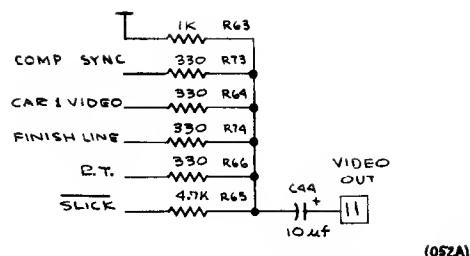


Figure 2-31. Video Summer

simultaneously returning a low to pin 3. A low at pin 3 forces a low to appear at pin 15 which goes around and causes pin 4 to be low which in turn causes pin 13 to be low. This continues until all the outputs are low and the latch is ready to record a new set of check point and car image intersections.

2-123. The information at 1A, 1B, 1C and 1D must be converted to a binary code by gates A2, A3, D2 and E2 so that multiplexer D4 can correctly address the ROM score image information. The truth table in Table 2-2 shows how this is accomplished.

2-124. D4 is a quad two-to-one multiplexer which selects either the score storage information or the game timer information. The signal is selected by 512H and the outputs of the multiplexer (B, C, D and E) become inputs to the ROM multiplexers. Basically, these outputs tell the ROM what number to look up and read out for the score and timer images stored within the ROM. The ROM only stores 17 sets of number display information (1 — 7 in tens and 0 — 9 in ones) which limits the numbers which can be displayed for the score and game timer. The lap score will count up to 78 and the game timer counts down from 78.

2-125. C4 is the ones counter for the game timer and B4 is the tens counter. When START goes low, these counters begin counting down from the number loaded into the parallel inputs (78) and count down by twos. When both counters reach zero, a low "borrow" (or END GAME) pulse is generated which resets the game to the attract mode. The length of the game can be changed by varying the 1 SEC pulses (see Section 1). Longer pulses are counted more slowly by the counters and thus the total game length is longer.

## 2-126. VIDEO SUMMER

2-127. The video summer shown in Figure 2-31 is simply a resistor summing network which collects all the video signals generated on the PCB, adds them across R63 and ac couples them to the TV monitor. The negative side of C44 is the point of connection for the video probe when troubleshooting.





